

# **Department of Aeronautics and Astronautics**

**Graduate School of  
Engineering and  
Applied Sciences**

**Naval  
Postgraduate School**

**Monterey • California**



# Education for the Warfighter

## Degrees

- Master of Science in Aeronautical Engineering
- Master of Science in Astronautical Engineering
- Aeronautical and Astronautical Engineer
- Doctor of Philosophy
- Doctor of Engineering in Aeronautical and Astronautical Engineering

## Students

- Joint Services (Navy, Air Force, Army)
- International Community
- 28 Astronauts are Aero/Astro Graduates
- Enrollment: Approximately 70 students

## Curricula

- Aeronautical Engineering
- Aeronautical Engineering (Avionics)
- NPS Test Pilot School Cooperative Program
- Space Systems Engineering

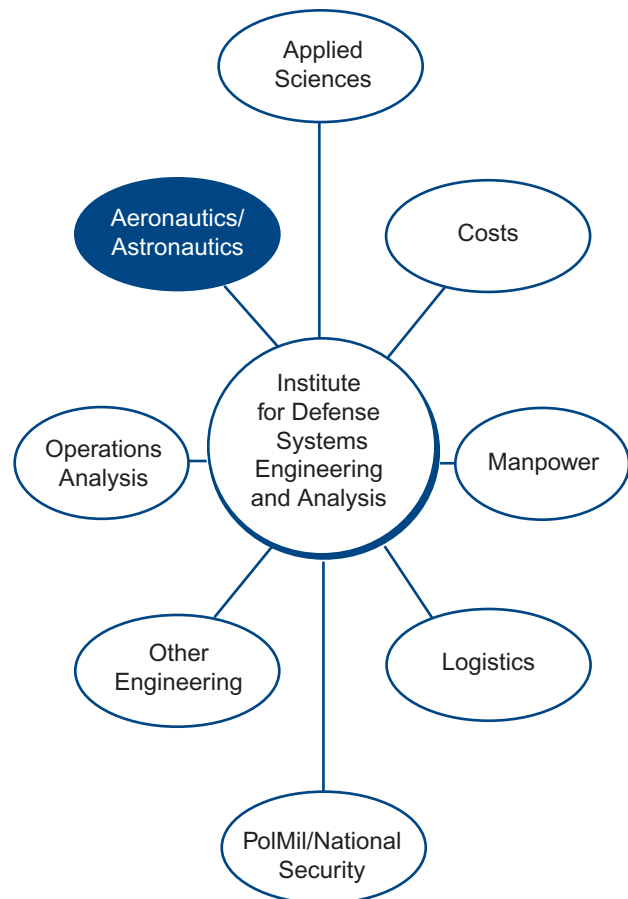
## Unique Courses

- Design (Aircraft, Helicopter, Missile, Aircraft Engine, Avionics, Spacecraft)
- Aircraft Combat Survivability
- Tactical Missile Propulsion

## Facilities

- Aerodynamics Laboratory
- Computation Laboratory
- Turbopropulsion Laboratory
- Gas Dynamics Laboratory
- Rocket and Combustion Laboratory
- Flight Mechanics Laboratory
- Flight Controls Laboratory
- Rotorcraft Laboratory
- Avionics Laboratory
- Structures and Composites Laboratory
- Survivability and Lethality Assessment Laboratory
- Aeronautical Design Laboratory
- Spacecraft Design Laboratory
- Space Systems Laboratories

## Interdisciplinary Systems Engineering Project



## Areas of Concentration

- Aerospace Vehicle Design
- Aerodynamics, Aeroelasticity, V/STOL Aircraft Technology
- Flight Mechanics and Controls
- Structures, Structural Dynamics, Composite Mechanics, Fracture and Fatigue
- Propulsion and Gas Dynamics
- Avionics
- Rotary Wing Aircraft Technology
- Aircraft Combat Survivability
- Spacecraft Systems, Attitude Control and Smart Structures
- Spacecraft Guidance, Control and Optimization

# Research

**Research Funding: \$2.86 million**

## Research Sponsors

- Naval Research Laboratory
- Office of Naval Research
- Naval Air Systems Command
- Naval Air Warfare Center-Aircraft Division
- Naval Air Warfare Center-Weapons Division
- Naval Surface Warfare Center-Carderock Division
- Naval Surface Warfare Center-Crane Division
- Naval Aviation Depot
- U.S. Army Research Office
- U.S. Army Yuma Proving Ground
- U.S. Army Comanche Program Office
- U.S. Army Materiel Command
- Air Force Research Laboratory
- Secretary of the Air Force
- National Aeronautics and Space Administration
- National Reconnaissance Office
- National Oceanic and Atmospheric Agency
- Florida A&M University
- Draper Labs
- California Institute of Technology
- General Electric Aircraft Engines
- Stirling Dynamics

## Technology Transfer

- Small Business Innovative Research (SBIR)
- Small Business Technology Transfer (STTR)
- Cooperative Research and Development Agreements (CRADA)
- Publications

## Research Centers of Excellence

- Navy-NASA Joint Institute for Aerospace Sciences
- Vertical Flight Technology Center
- Aerodynamics Decelerator Systems Center
- Turbopropulsion Laboratory
- Spacecraft Research and Design Center

# Faculty and Technical Staff

- 12 Tenured or Tenure-Track Faculty
- 10 Research Professors and Research Associates
- 1 Senior Lecturer and 1 Military Faculty
- 3 Aerospace Engineers
- 3 Aerospace Technicians

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# Introduction

The Department of Aeronautics and Astronautics is an integral part of the Graduate School of Engineering and Applied Sciences. Aero/Astro faculty members conduct research and teach courses covering air and space vehicles, missiles, propulsion, aerodynamics, avionics, control systems, structures, turbomachinery, computational and experimental methods, orbital mechanics and combat survivability that emphasize total systems design. The uniqueness of this approach is that air and space vehicles are considered part of a larger combat system that includes all aspects of warfighting.

Navy and Marine Corps aircraft are designed to operate aboard ships as part of a larger battlegroup. Challenges normally not considered by aircraft operating from land bases become design constraints for shipboard compatibility. By working in a Total Systems Design Group, Aero/Astro faculty and students are exposed to the constraints of shipbuilding, software development and weapons compatibility. Additional issues such as acquisition methods, analysis of alternatives, and order of battle scenarios can be explored by working with the Graduate School of Business and Public Policy, the Graduate School of Operations and Information Sciences, and the School of International Graduate Studies. Aero/Astro faculty and students are exposed to a wide variety of disciplines to develop capable runway-independent aircraft and robust space systems.

## Chairman's Message

The decisive role played by ship-based aircraft in World War II left no doubt at war's end about the need to fully transition from battle ship to carrier-based naval operations. This, in turn, required the transition from piston engine powered propeller aircraft to gas turbine powered jet aircraft. To support the technical challenges posed by this transition, Dr. Wendell Coates, an engineering instructor in the Naval Postgraduate School located on the Naval Academy campus, proposed and obtained approval to establish an aeronautical engineering department in 1947. He served as its chairman until 1962 and, after the School's transfer to Monterey, was instrumental in attracting additional faculty and providing the Department with outstanding laboratories. Important additions to the Department's curricula occurred in 1979 and 1987, respectively, when the joint Naval Postgraduate School/Naval Test Pilot School and the space systems engineering/operations curricula were implemented. Both additions reflect the Navy's recognition of the continuing need for flight test expertise and the growing use of satellites for naval operations.

The philosophy used to guide the formulation of the Department's educational objectives can perhaps best be summarized by quoting a remark which Coates' successor, Dr. Richard Bell, made to me shortly after I joined the Department in 1970, "Always remember that the sole reason for the Department's existence is its responsiveness to the sponsor requirements." This prompts me to elaborate a bit on these requirements. Clearly, it is essential that the quality of instruction and the faculty expertise and productivity are and remain competitive with that offered at leading civilian uni-

versities. Therefore, the aeronautical and astronautical engineering curricula must meet the standards set by the Accreditation Board for Engineering and Technology (ABET). Our aeronautical engineering curriculum has been fully accredited for the past fifty years; the astronautical engineering curriculum became accredited in 1995. Both curricula were reviewed again by ABET in October 2001, and we expect to receive continued full ABET accreditation in July 2002.

In addition to the ABET requirements, our two curriculum sponsors, the Naval Air Systems Command and the Naval Space Systems Division, impose several additional requirements, namely:

- **Cost Effective Education:** In order to minimize the time spent on graduate studies the Department offers year-round instruction and course sequencing such that the officer students may enroll at any time during the year. Also, students who would not attempt a graduate degree because of their undergraduate background or their time away from academia are brought up to the necessary standards.
- **Broad-Based Engineering Education:** The officers need to be provided with a broad-based aeronautical or astronautical engineering education to qualify for future assignments in a variety of jobs rather than in a narrow specialty. Also, they need to be familiarized with modern computing, design, measurement and testing techniques. This calls for the availability and maintenance of modern laboratories.
- **Navy/DoD Relevant Engineering Education:** The officers need to be familiarized with problems in past and current aircraft and weapon systems developments



in order to sensitize them to the current state-of-the-art and to the uncertainties involved in a typical development program. This calls for faculty with previous industrial experience and strong involvement in current Navy/DoD projects.

- **Total Systems Design Education:** It is well

recognized that the success of any aircraft or spacecraft crucially depends on competent integration of all the disciplines needed for their design and development. Thus, a comprehensive capstone design project has been made a firm requirement in both curricula. Moreover, the aircraft or spacecraft, in turn, is part of a larger weapons system. Therefore,

there is a need to expose the students to the “Total Systems Design” approach. By working together with other students and faculty in the recently established Institute for Defense Systems Engineering and Analysis, Aero/Astro students learn how air and space vehicles become part of a larger combat system that includes all aspects of warfighting. The recently completed “Crossbow” study is an example of the type of total systems design studies requiring the participation of Aero/Astro faculty and students, together with faculty and students from other departments and Schools.

Finally, it is important to keep in mind that an engineering education (in contrast to training) can never impart the specific knowledge required to tackle any new engineering problem our graduates may encounter in their later careers. Instead, the objective of education is to equip the graduate with what I call “good engineering judgment.” By this I mean that he/she should have acquired the critical thinking and tools to assess whether a proposed approach is compatible with the basic laws of physics and he/she should have acquired an understanding of the limits of our analysis tools. There is a tendency these days to believe in the power of our computational simulation abilities and thus to regard aeronautical and astronautical engineering as “a mature technology.” I first encountered this attitude while employed at the Lockheed-Georgia Company, during the development of the C-5 Galaxy aircraft. The assumption was that aircraft technology was so well in hand that the company should be able to develop and build 110 aircraft at a fixed price within a specified

time. This DoD imposed Total Package Procurement concept led to the delivery of aircraft with a vastly reduced wing fatigue life necessitating the rewinging of all aircraft at a huge extra cost. This concept reflected a fundamental misunderstanding of the state-of-the-art by the “experts” who imposed this scheme.

I mention this personal experience to emphasize the need for an engineering education that clarifies the limits of our understanding of the technology and thus sensitizes the officers to the uncertainties involved in a typical development program. Although tremendous progress has been made over



the past forty years there are still many areas of uncertainty. A technically competent graduate therefore can have a decisive impact on the planning, development and acquisition of future weapons systems. It is an aspect of engineering education that is difficult to quantify and therefore is often omitted in justifying its value.

The recent military operations in Afghanistan show that, for the foreseeable future, there will be an urgent requirement to monitor terrorist activities and to deliver precision guided munitions quickly and effectively from sea or airborne platforms operating independent of military bases in foreign countries. This type of operation will require systems which pose new and demanding aerospace engineering challenges. It therefore appears that the rapid aerospace engineering advances we have witnessed in the past century will continue well into the 21st century. The Aero/Astro faculty of the Naval Postgraduate School looks forward to continue educating the aerospace engineering student officers about the current and future technological opportunities and to participate in large weapons systems studies. I hope that this brochure will provide some information about the Department's instructional programs, faculty expertise and areas of concentration, laboratories, projects, etc. My colleagues and I will be pleased to provide additional details on request.

Max F. Platzer  
Distinguished Professor and Chairman

# Education for the Warfighter

The Department of Aeronautics and Astronautics provides advanced education in Aeronautical and Astronautical Engineering to develop technical subspecialists in the field. Upper division undergraduate and graduate courses are offered in aerodynamics, astrodynamics, structures, guidance and control, flight mechanics, avionics, propulsion and design, with applications to rotary wing and fixed wing aircraft, missiles and spacecraft.

The typical graduate from the normal two-year NPS Aeronautical or Astronautical Engineering curricula is a career military officer who will, in the future, encounter many technical challenges currently unknown by both the student and the faculty. As a result, the best education is believed to consist of a program that will address the fundamentals of engineering and scientific principles, including experience in the application of these principles to unique Navy/DoD problems and issues. The NPS student population is composed of representatives from the U.S. services and international community. This joint, international class composition provides additional leverage in defining the challenges of the future.

## Curricula

The department offers four curricula, which are available to U.S. and foreign military officers and U.S. government civilian employees.

- Aeronautical Engineering
- Aeronautical Engineering (Avionics)
- NPS/Test Pilot School Cooperative Program
- Space Systems Engineering

The Aeronautical Engineering Programs are designed to meet the specific needs of the Navy technical managers with a broad-based graduate education in Aeronautical Engineering. These programs give the student a broad aeronautical engineering education in the following principal areas of aeronautics: aerodynamics, flight mechanics, propulsion, flight structures, avionics, and systems integration. Additionally, students receive graduate level instruction in aircraft/missile design and aero-computer science. The programs are divided into preparatory, graduate and advanced graduate phases. During the advanced graduate phase, all students receive in-depth graduate coverage through advanced electives in areas of their choice including flight dynamics, gas dynamics, propulsion, structures, avionics, and aircraft or missile design.

The NPS/Test Pilot School Cooperative Program combines portions of the Aeronautical Engineering and Aeronautical Engineering (Avionics) curricula with the complete U.S. Naval Test Pilot School syllabus. After completion of the requirements at NPS, students proceed to Patuxent River for the full Test Pilot School Curriculum. This program is very competitive, and students accepted to this

program are typically exceptional undergraduate engineering students and aviators who are capable of completing all the graduate education coursework in 5-6 quarters. Graduates receive the masters degree in Aeronautical Engineering at the completion of test pilot school.

The Astronautical Engineering program provides officers with a comprehensive scientific and technical knowledge of military and Navy space systems through graduate education. This curriculum is designed to equip officers with the theoretical and practical skills required to design and integrate military space payloads with other spacecraft subsystems. Graduates will be prepared by their education to design, develop and manage the acquisition of space communications, navigation, surveillance, electronic warfare and environmental sensing systems.

## Degrees

The Department of Aeronautics and Astronautics and the degree Master of Science in Aeronautical Engineering have been accredited by the Accreditation Board for Engineering and Technology since 1949. The degree Master of Science in Astronautical Engineering has been accredited by the Accreditation Board for Engineering and Technology since 1995. The degree Aeronautical and Astronautical Engineer is offered in the Department of Aeronautics and Astronautics and requires a minimum of 72 hours of graduate course credit.

The Department of Aeronautics and Astronautics offers programs leading to the doctorate. Entrance into the doctoral program may be requested by officers currently enrolled in the Aeronautical and Astronautical Engineers Degree Program who have sufficiently high standing. The Department of Aeronautics and Astronautics also accepts officer students selected in the Navy-wide Doctoral Study Program and civilian students selected from employees of the United States federal government. A distinctive feature of the program leading to the Doctor of Engineering degree is that the student's research may be conducted away from the Naval Postgraduate School in a cooperating laboratory or other installation of the federal government.

## Unique Courses

Students are required to participate in a major design project where they contribute as a member of a design team to an aircraft, avionics, spacecraft or missile design project. At the conclusion of the design project, the students have to present their contributions to a committee of military and industry experts. Many times the NPS design team competes with other universities in AIAA or AHS sponsored design competitions. NPS students have consistently ranked high in these competitions thus lending credence to the quality of their efforts.

Two other unique Aero/Astro courses offered at NPS are Aircraft Combat Survivability and Tactical Missile Propulsion. Aircraft Combat Survivability brings together all of the essential ingredients in a study of the survivability of fixed wing aircraft, rotary wing aircraft, and cruise missiles in a hostile (non-nuclear) environment. The technology for increasing survivability and the methodology for assessing the probability of survival in an AAA/SAM environment are presented in some detail. Topics covered include: current and future threat descriptions, the mission/threat analysis, combat analysis of SEA and Desert Storm losses, vulnerability reduction technology for the major aircraft systems, susceptibility reduction concepts, including stealth, vulnerability, susceptibility and survivability assessment, and trade-off methodology.

Tactical Missile Propulsion covers applications and analysis of solid propellant rockets, ramjets, dual-combustion ramjets, scramjets, ducted rockets, and pulse detonation engines to include: propellant selection criteria and characteristics, combustion models and behavior, performance analysis, combustor design, combustion instabilities and damping, mission and flight envelope effects on design requirements and technology requirements, use of performance and grain design codes and laboratory test firings for comparison with measured performance of rockets and ramjets, and an introduction to insensitive munitions and plume signature considerations.

### **Non-Resident Programs**

In addition to the resident programs, a distance learning degree program is available. Civilian engineers assigned to the Naval Air Warfare Centers are eligible to enroll in a degree program at NPS. Through a combination of VTC and in-resident courses, these students can earn the necessary credits to receive their degree of Masters of Science in Aeronautical Engineering. Typically, their thesis involves current research sponsored by Naval Air Systems Command and may be a pivotal part of a project for which they are responsible in their normal duties.

Several short courses have also been developed and are delivered at different military installations. Short Courses currently offered include:

- Computational Fluid Dynamics
- Engineering Risk Assessment
- Aircraft Fatigue and Fracture
- Loads and Dynamics
- Aircraft Combat Survivability

### **Experience Tours**

All aeronautical engineering students are eligible to participate in a funded, curriculum-sponsored experience tour. This tour is normally six weeks and is taken during the second Winter Quarter, with the remaining six weeks taken up by three accelerated courses. The student chooses the location for this experience tour with the help of a thesis advisor according to the thesis topic and the availability of the host institution. Typical locations are government

research centers such as those run by NASA, DoD laboratories and aerospace-company research laboratories. This experience tour counts as one of the four thesis slots that are allocated for the master's degree. It is possible to spend the tour at more than one location and may include attendance at a technical conference or a technical visit during the tour.

Aeronautical engineering students may participate in a less formalized experience tour. Here, the student spends up to one full quarter at a laboratory where work in the area of the student's thesis topic is taking place. This is done by arrangement only and the thesis advisor is the resource person for both sponsoring and for securing the host location. A typical example is in the rotorcraft field where a student spends one quarter at NASA Ames as a participant in one of their research programs.

### **Student Theses**

Students are required to complete a thesis project in order to receive their degree. The thesis serves as an integral part of the NPS education process by giving students an opportunity to conduct individualized research in a subject of their choosing. At the completion of their thesis project, students present their work to the faculty and students. Often, the student's contribution is part of a larger research project by his/her thesis advisor, and therefore is routinely presented by the student (or his/her advisor if the student has already graduated) at scientific conferences and published in scientific journals. An exception to the thesis requirement is made for the NPS/TPS students, whose final flight test report at TPS serves in lieu of a thesis.

### **Interdisciplinary Projects**

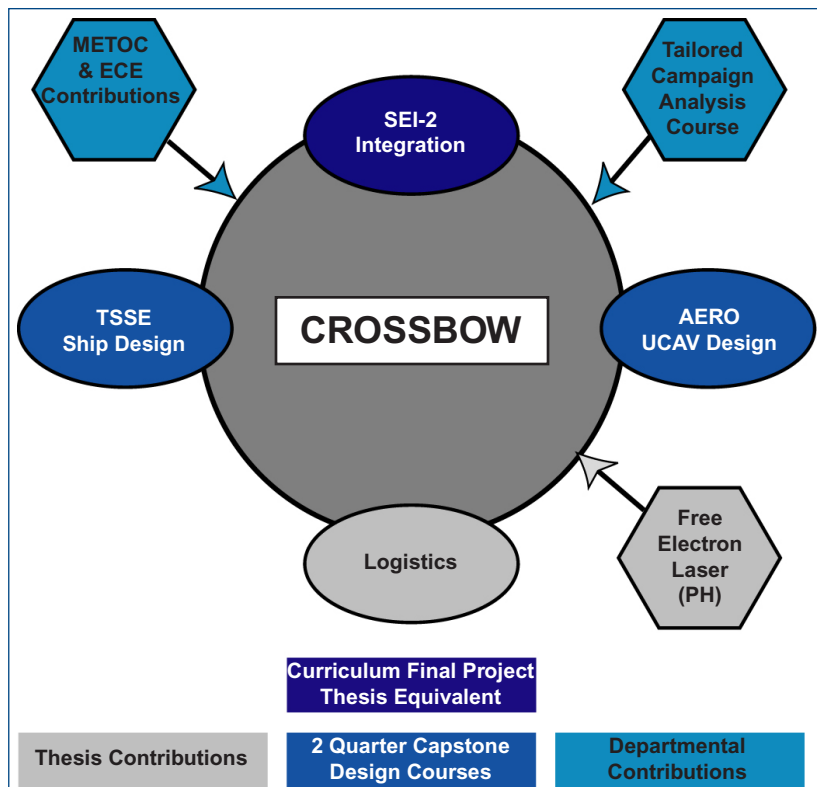
Interdisciplinary efforts combine faculty and students from across campus. The Department of Aeronautics and Astronautics is an integral partner in several interdisciplinary projects. The latest collaborative effort is described below.

**Total Weapons Systems Design:** The Institute for Defense Systems Engineering and Analysis supports a multi-disciplinary student project each year. This project brings together students from across campus to participate in a "total concept" analysis. Students from the engineering disciplines provide the technical design, operations research students provide logistics and analysis, national security affairs students provide political-military perspectives, business students address manning and costs, applied science (oceanography/meteorology/physics) students tackle the environment.

The project for 2001 was called "Crossbow." The Crossbow originated with the President of the Naval War College who proposed studies to determine the feasibility and operational worth of a small, high-speed aircraft carrier concept. NPS students chose to pursue a high-speed ship design that supports an air wing composed primarily of Unmanned Air Vehicles. Crossbow combines a SEA LANCE (or "street fighter") variant (*SEA LANCE II*) with

*SEA ARCHER* (a small high-speed carrier), and *SEA QUIVER* (a notional high-speed support ship). The *SEA ARCHER* air wing comprises 8 multi-mission SEA ARROWS, Unmanned Combat Air Vehicles (UCAVs), 8 multi-mission support UAVs and 2 MH-60 multi-mission helicopters.

During the 2002 and 2003 academic years, NPS will embark on a major study of expeditionary and amphibious warfare. In addition to participation by aeronautical and astronautical engineering students, there will be students from the Systems Engineering and Integration curriculum, the Total Ship System Engineering curriculum and numerous other curricula on campus, including logistics, C4I, intelligence and others. A dozen or more faculty members are expected to contribute. The project is expected to take a top-down look at expeditionary warfare, establishing capability needs and exploring alternatives for meeting those capabilities unconstrained by existing programs or assets.



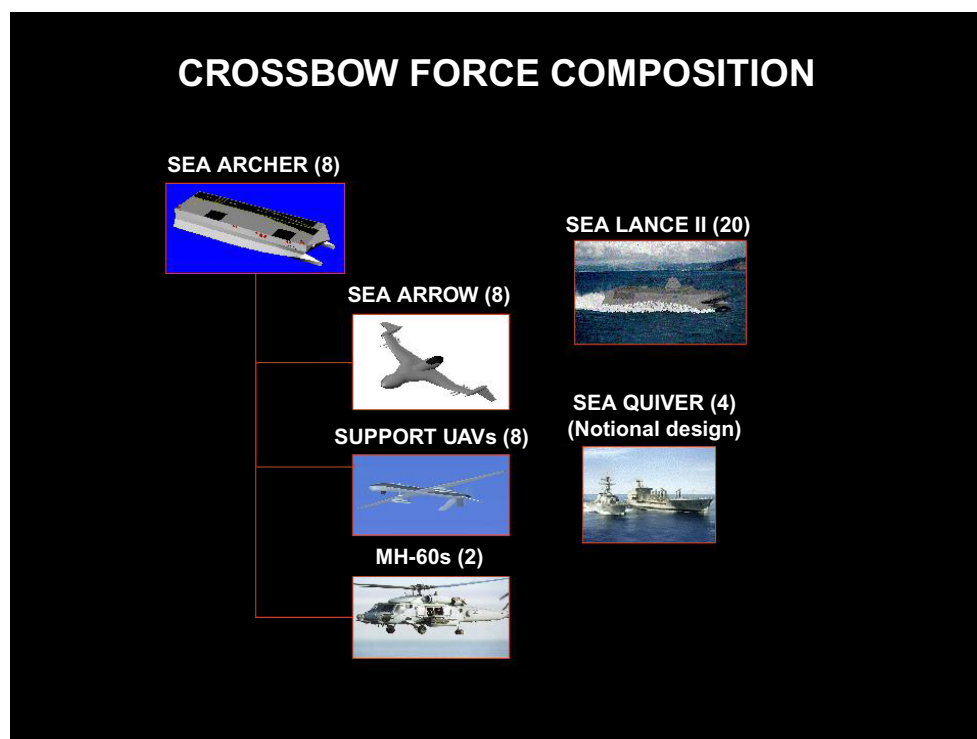
## Facilities

Laboratories support instructional and research programs in aerodynamics, flight mechanics, flight controls, avionics, structures and composite materials, scientific computing, aircraft and spacecraft design, gas dynamics, turbopropulsion, rocket and ramjet propulsion, and dynamics and nondestructive evaluation.

*The Crossbow project brought together students from across campus to participate in a “total systems design.”*

Facilities/laboratories in the Department of Aeronautics and Astronautics include:

- Aerodynamics Laboratory
- Computation Laboratory
- Turbopropulsion Laboratory
- Gas Dynamics Laboratory
- Rocket and Combustion Laboratory
- Flight Mechanics Laboratory
- Flight Controls Laboratory
- Rotorcraft Laboratory
- Avionics Laboratory
- Structures and Composites Laboratory
- Survivability and Lethality Assessment Laboratory
- Aeronautical Design Laboratory
- Spacecraft Design Laboratory
- Space Systems Laboratories





# Areas of Concentration

The Department of Aeronautics and Astronautics prime areas of concentration include:

- Aerospace Vehicle Design
- Aerodynamics, Aeroelasticity, V/STOL Aircraft Technology
- Flight Mechanics and Controls
- Structures, Structural Dynamics, Composite Mechanics, Fracture and Fatigue
- Propulsion and Gas Dynamics
- Avionics
- Rotary Wing Aircraft Technology
- Aircraft Combat Survivability
- Spacecraft Systems, Attitude Control and Smart Structures
- Spacecraft Guidance, Control and Optimization

## Aerospace Vehicle Design

Aerospace vehicle design, by its very nature and definition, comprises the design of a complete vehicle (fixed or rotary-wing aircraft, missile or spacecraft), although it includes component and/or subsystem design, e.g., engine or motor design. Aircraft and spacecraft design is the discipline of integrating the aerodynamic, materials, structural, propulsion, control, dynamics, stability, performance, and gas dynamic attributes of a system into a survivable, maintainable, reliable vehicle that will meet a specified need, at an affordable cost, with acceptable risk. Multidisciplinary design is the essence of engineering. Aerospace design activities are team oriented and multidisciplinary by their very nature.

The Department of Aeronautics and Astronautics provides its students with a broad range of design opportunities. Two-course sequences are provided in aircraft (fixed wing) and spacecraft design. Single design courses are offered in missile, rotary-wing and airbreathing engine design. A one-course avionics design course is also available. A Spacecraft Design Laboratory facilitates spacecraft design efforts. An Aeronautical Design Laboratory facilitates fixed-wing, missile rotary-wing, and engine design. Avionics design is conducted in a dedicated laboratory with its own unique equipment. The multitasking, synergistic activities of each design team requires a dedicated laboratory to provide continuity and maximize the efficiency (utilization of student time) of the student design effort.

### Aircraft Design

Aircraft design at the Naval Postgraduate School is taught in a team environment. Each team consists of some 6-10 students functioning as an IPPD Team. The team design effort is a response to a Request-for-Proposal (RFP). The design effort is distributed over two consecutive quarters, one class each quarter.

In the first quarter, the students define a design

solution space bounded by the RFP requirements (constraints); develop some four Quality Function Deployment (QFD) matrices (customer requirements through manufacturing); evaluate a minimum of four possible configurations (down-select to one configuration for final analysis and evaluation); perform sensitivity analysis (Taguchi) for both weight and cost; develop an inboard profile; compute shear, bending moment, torsion, rotation, and deflection curves for the various aircraft components (wing, fuselage, and control surfaces) under aerodynamic and inertial loading; and prepare an interim report. During this quarter the students also learn to utilize aircraft design related software available in the design laboratory. This software includes Advanced Aircraft Analysis (AAA), Rapid Aerodynamic Modeling (RAM), Air Force DATCOM, Quality Function Deployment (QFD), and GASTURB. Students are expected to write their own weight prediction, cost prediction, specific excess power (Ps), performance, and stability and control characteristics software (Excel and/or MATLAB).

In the second course, the design team members finalize the aircraft design in terms of configuration, structure, performance, stability and control, cost, weight, survivability, project risk, environmental emissions, measures of effectiveness, landing gear, and signatures (RCS and IR). A 50-minute oral presentation of the design is presented to an invited Industry/Government Review Board (I/GRB), followed by an I/GRB critique. A 100-page report summarizing the design is also prepared.

One indication of the quality of the design experience is evidenced by NPS team placements in American Institute of Aeronautics and Astronautics (AIAA) national graduate student design competitions. Design awards are shown in the table below. However, not every NPS aircraft design team enters a national competition. During 1993, 1994, and 1996, for example, an M = 6 waverider configured interceptor was the focus of the student design effort. For

the past two years, NPS Aero/Astro design teams have developed a number of UCAV configurations of interest to NAVAIR (ONR).

## Missile Design

Interested students may take an elective five-course sequence in missile systems. Courses in missile aerodynamics, tactical missile propulsion, missile flight analysis, and air defense lethality precede a single course in missile design. Missile design activities are conducted in the same manner described above for fixed-wing aircraft design.

The 6-10 person missile design team responds to an RFP, performs conceptual sizing trade studies, and down-selects from four-or-more configurations to a single configuration. In addition to the software used by the aircraft design students, the missile design students use MISSILE DATCOM and ADAM software. Detailed structural, aerodynamic, propulsion, stability and control, trajectory analysis, and warhead lethality analysis are performed. Measures of effectiveness are estimated. Also cost, performance, and project risk estimates are computed. An oral presentation of the final design is made to an I/GRB and a 100-page report summarizing the design effort is prepared.

## Rotary-Wing Design

The procedures for design of helicopters and other types of rotorcraft parallel that of fixed-wing aircraft design. Typically, 6-10 students work on the helicopter design project, which is a response to a Request for Proposal (RFP) written by one of the three major U.S. helicopter manufacturers (Sikorsky, Boeing, and Bell). The design competition is sponsored, judged and managed by the American Helicopter Society (AHS).

### Design Awards

1999 AHS/NASA Student-Industry Helicopter Design Competition: 2nd Place  
1998 AIAA Foundation Graduate Team Aircraft Design Competition: 3rd Place  
1998 AHS/NASA Student-Industry Helicopter Design Competition: 2nd Place  
1997 AHS/NASA Student-Industry Helicopter Design Competition: 2nd Place  
1997 AIAA/McDonnell Douglas Aircraft Design Contest: 1st and 2nd Place  
1997 AIAA/Lockheed Martin Spacecraft Design Contest: 2nd Place  
1997 AIAA/Rockwell/Rocketdyne Engine Design Contest: 2nd Place  
1997 AIAA/Northrop Grumman Missile Design Contest: 2nd Place  
1996 AHS/NASA Student-Industry Helicopter Design Competition: 2nd Place  
1996 AIAA/McDonnell Douglas Aircraft Design Competition: 1st and 2nd Place  
1995 AHS/NASA Student-Industry Helicopter Design Competition: 1st Place



*Student design (2000) of helicopter for U.S. Special Operations Command.*

In their analysis for the response, the students use primarily NPS generated software that works with the MATLAB and Simulink computational languages. The primary analysis tool used by the design team is JANRAD (Joint Army-Navy Rotorcraft Analysis for Design) which was developed by several students as part of their thesis project. JANRAD has the built-in capability for trimming the rotor, calculating rotor blade loads in hover and forward flight, establishing rotor power required as well as parameters such as collective pitch, cyclic pitch, blade coning and flapping, and rotor dynamic loads. A separate part of JANRAD is used for stability and control calculations.

Students in the helicopter design class at NPS have established an impressive record in the AHS national design competition as shown above. However, in some years the school chooses not to compete, but instead focuses on military unique designs, such as an advanced concept light helicopter for the U.S. Special Operations Command shown in the diagram above. The design requirements imposed by these military customers are usually more demanding than their civilian counterparts, making for a challenging design project.

## Engine Design

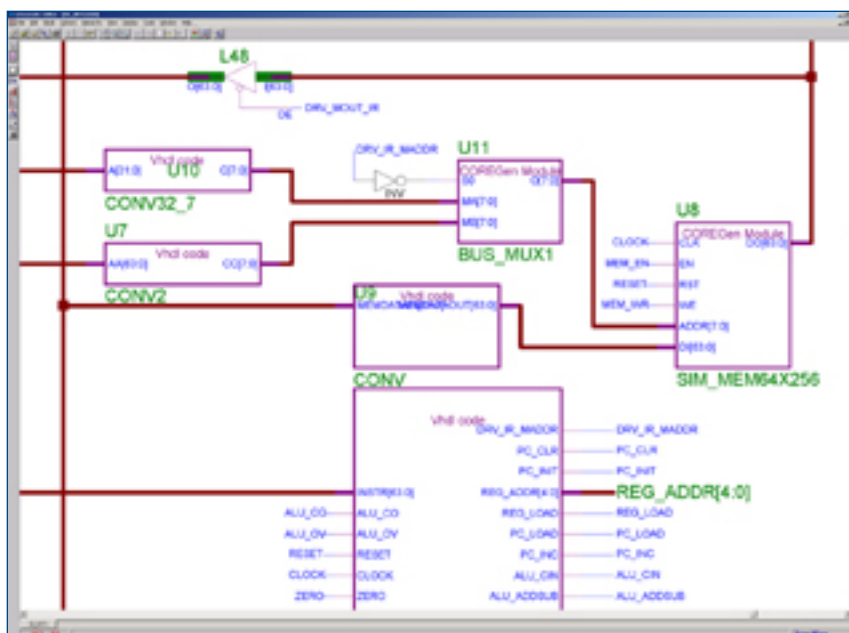
An engine RFP, either a past military RFP or from a current AIAA competition, is selected for the course. For example, the JAST RFP (which evolved into the Joint Strike Fighter (JSF) program) was chosen as the design problem when the course was concurrently taught by Distance Learning to the Naval Air Warfare Center. Each student performs constraint and mission analyses, selects and sizes an engine in the first half of the course. A selection is then made from these candidate designs. In the second half of the course, the class working as a team carries out the preliminary design of the components. GASTURB is used in the engine selection phase. Codes developed in-house are used for the fan, compressor and turbine designs.

## Avionics Design

Digital design and hardware/software integration are taught through a series of small design projects and a more complex final project such as the development of video controllers or serial communications controllers. PCs are equipped with modern CAD software and instrumentation for digital design. Designs may be entered in any combination of schematics, HDLs (Hardware Description Language) including VHDL and Verilog, or commercially available IP (Intellectual Property) modules. Hardware designs are verified using computer-aided functional and timing simulation tools. Assembly language and C programs are verified using microprocessor simulation programs and commercial software development tools. The designs are then implemented using combinations of FPGAs (Field Programmable Gate Arrays ranging from 10,000 to 1,000,000 gates) and micro-controllers. The designs are then verified using PC-based logic analyzers and digital oscilloscopes.

## Spacecraft Design

The spacecraft design is taught in a laboratory that uses computer-aided design tools, such as GENSAT, Aerospace Conceptual Design Center software, STK, NASTRAN, IDEAS, and MATLAB/Simulink. During summer 2000, the students finished a preliminary design of a Bifocal Relay Mirror Spacecraft under the sponsorship of Air Force Research Laboratory (AFRL). The Bifocal Relay Mirror Spacecraft is composed of two opti-



*Schematic of a Student's Microprocessor Design.*

cally coupled telescopes used to redirect the laser light from ground-based, aircraft-based or spacecraft-based lasers to a distant point on the earth or in space. The design effort identified the need to develop new technologies for beam acquisition, tracking and pointing.

## Total Weapons Systems Design

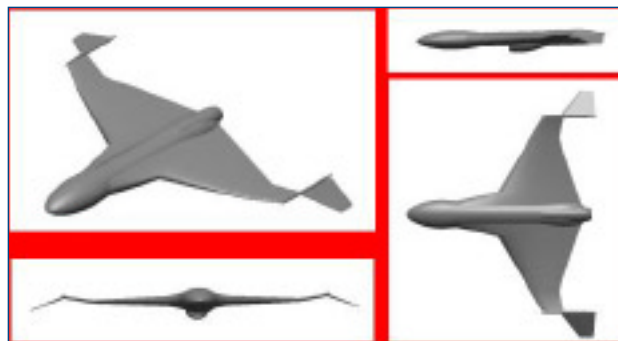
During the 2001/2002 academic year, the Department of Aeronautics and Astronautics aircraft design teams worked with the Total Ship System Engineering (TSSE) students (ship design) and the Systems Engineering students (system requirements) to develop the CROSSBOW battleforce system.

CROSSBOW is

essentially a small, fast carrier task force supporting global, littoral warfare scenarios. The Systems Engineering students developed the CROSSBOW ship and aircraft requirements. The TSSE students designed the small, fast carrier, *SEA ARCHER*. The Aeronautics/Astronautics students designed two aircraft capable of operating from the *SEA ARCHER*. *SEA ARROW* was designed for an armed reconnaissance (UCAV) mission; *SEA SPECTRUM* was designed for intelligence, surveillance, reconnaissance and combat (ISRC) UCAV mission. *SEA SPECTRUM* also has the capability to operate unassisted from an LHA.



*Students working in the Spacecraft Design Laboratory.*



*The SEA ARROW configuration is shown. It is a subsonic, semi-tailless 15,000 lb. aircraft, with a loiter Mach number of  $M = 0.34$  and a maximum Mach number of  $M = 0.8$ . It is expected to have a flyaway cost of \$9.5M and reasonable maintainability ( $MMH/FH = 8.79$ ).*

# Aerodynamics, Aeroelasticity, V/STOL Aircraft Technology

A better understanding of viscous flow effects throughout the whole Mach number and Reynolds number regimes continues to be a serious challenge for the design and operation of various aerospace vehicles and propulsion systems. Of special importance is the prediction and measurement of the onset of flow separation (stall) on airfoils, three-dimensional wings, and helicopter and jet engine blades. Viscous flow computations using Navier-Stokes codes are therefore performed in the Computation Laboratory which has 17 Silicon Graphics workstations and a parallel cluster of fifteen PCs running Linux, augmented by computations on NASA and DoD supercomputers. Experiments are performed in the Aerodynamics Laboratory which consists of a low-speed flow visualization tunnel with a 5x5 test section and a 15x20 inch water tunnel. Laser Doppler velocimetry is available in both tunnels. Furthermore, a special wind tunnel is available at the NASA Ames Research Center to perform dynamic stall measurements using a special flow visualization and measure-

ment technique, Point Diffraction Interferometry

Current projects comprise computational and experimental investigations of the aerodynamic and aeroelastic characteristics of micro-air vehicles, helicopter blades, VTOL aircraft lift fans, fighter/attack aircraft, jet engine bladings, and hypersonic missiles. Therefore, the aerodynamic phenomena that are being studied cover the complete Mach number and Reynolds number range. Another project concerns the development of helicopter blades capable of controlling the onset of dynamic stall. Also, a new type of lift fan, the cross-flow fan, is being investigated experimentally and computationally to analyze the aerodynamic fan characteristics, optimize thrust and propulsive efficiency, and determine the applicability of cross-flow fans to VTOL aircraft.

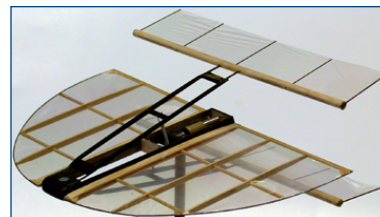
**Personnel:** Distinguished Professor Max Platzer, Professor Garth Hobson, Professor E. Roberts Wood, Research Professor M.S. Chandrasekhara, Research Associate Professor Kevin Jones, CDR Mark Couch, USN.

## Current Work

### Development of Micro Air Vehicles Using Flapping-Wing Propulsion

*Sponsor/Collaborator: Naval Research Laboratory*

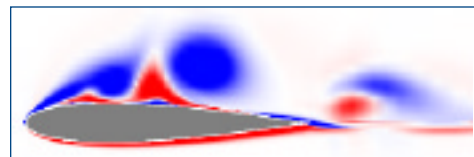
- 6" span and length
- Models weigh 6 to 10 grams
- Composite construction
- Vertical take-off demonstrated



### Unsteady Aerodynamic and Flutter Analysis of Airfoils and Jet-Engine Bladings

*Sponsor/Collaborator: University of Kentucky/NASA Glenn*

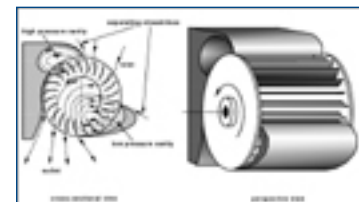
- Subsonic and transonic flight regimes
- Analysis of viscous flow effects
- Separation bubbles
- Dynamic stall



### Cross-Flow Fan (CFF) Propulsion for VTOL Aircraft

*Sponsor/Collaborator: NASA Glenn*

- Numerical analysis of the CFF flowfield
- Experimental evaluation of the flow and thrust characteristics
- Design optimization



### Helicopter Blade Dynamic Stall Control

*Sponsors/Collaborators: Army Research Office/Army Materiel Command/AFDD*

- Aims to delay stall on helicopter blades
- Novel approach of dynamically deforming leading edge airfoil
- Uses advanced measurement techniques



# Flight Mechanics and Controls

Extensive teaching and research work in these areas address real fleet-and-field problems in the areas of unmanned air vehicle performance, flying qualities, guidance navigation and control, precision airdrop of military re-supply and humanitarian aid as well integrated plant controller optimization issues for high speed civil transport aircraft. Several laboratories support this work.

- The Flight Simulation Laboratory includes a Singer-Link GAT-1 General Aviation full-motion flight simulator and a 2F90 TA-4J full-motion flight simulator. These simulators are used to support the flight dynamics and flight-test engineering courses.
- The Unmanned Air Vehicle Flight Research Laboratory (UAV FRL) is used to conduct flight research with

scaled radio-controlled and semi-autonomous aircraft to study problems identified with fleet UAVs and to design, implement and test new concepts in flight performance, flying qualities, guidance, navigation and control. Research vehicles include fixed-wing and rotary wing platforms. Data recording is by telemetry and on board data logging, depending upon the application.

- The Low-Speed Aerodynamics Laboratory includes two wind tunnels: one is a 28x45inch test section wind tunnel capable of speeds of up to 120 knots, and the other is a 3x5 foot test section wind tunnel capable of speeds of 150 knots. Both tunnels have data acquisitions systems for measurement of surface pressures and of forces and moments with the use of a six-component sting balance.

## Current Work

### Development of Integrated Tail-Sizing and Control Tools for High Speed Civil Transport (HSCT)

*Sponsor/Collaborator: NASA Langley*

- Developed a new tail sizing tool that determines how far back the HSCT center of gravity can be moved before there exists no autopilot that can recover from a severe gust using existing control surface actuators.

### Nonlinear Navigation for Unmanned Air Vehicles Using Passive Sensors

*Sponsor: Office of Naval Research*

- Developed new nonlinear navigation algorithms that integrate infrared vision and inertial sensors to provide

precise estimates of relative position, velocity and orientation of an UAV with respect to a ship in the presence.

- These algorithms perform well in the presence of severe weather constraints and in the presence of out-of-frame events when the infrared camera loses sight of a ship.

### Formation Flight Control of Unmanned Air Vehicles

*Sponsor/Collaborators: University of California-Los Angeles, NASA-Goddard*

- Provide flight test support to UCLA for testing new formation flight guidance, navigation and control algorithms.

*Unmanned Air Vehicle (UAV) "Frog" at the Naval Postgraduate School.*



- The Flight Controls Laboratory presently consists of four hardware-in-the-loop stations designed to conduct extensive hardware-in-the-loop studies of guidance, navigation and control systems. These stations are supported by a family of Realsim and MATLAB rapid prototyping tools.

**Personnel:** Associate Professor Richard Howard, Associate Professor Isaac Kaminer, Associate Research Professor Oleg Yakimenko, National Research Council Research Associate Vladimir Dobrokhodnov, Aerospace Physicist Jerry Lentz, UAV Pilot Don Meeks

## Current Work

### Continued Development of Affordable Guided Air-drop System (AGAS)

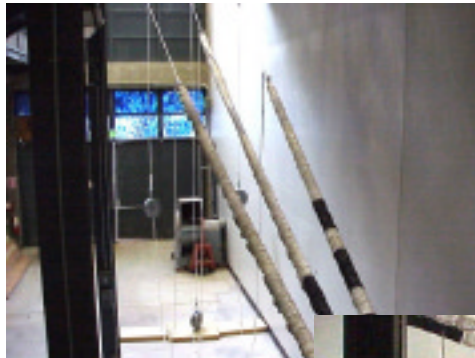
*Sponsor/Collaborator: U.S. Army Yuma Proving Ground*

- Developed a high fidelity 6 DOF model of a controllable round canopy parachute.
- Developed and successfully flight tested new GNC algorithms that steer a parachute to a point on the ground with prescribed tolerance.

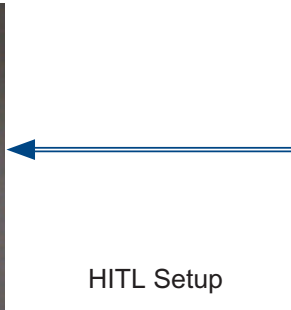
### Personnel Parachute Instrumentation Development

*Sponsor/Collaborator: U.S. Army Yuma Proving Ground*

- Low-cost portable sensor and data-acquisition package.
- Measure and record angular rates, accelerations, pressure and GPS data for attitude and trajectory.
- For comparison testing of new parachute designs and follow-on development and testing.



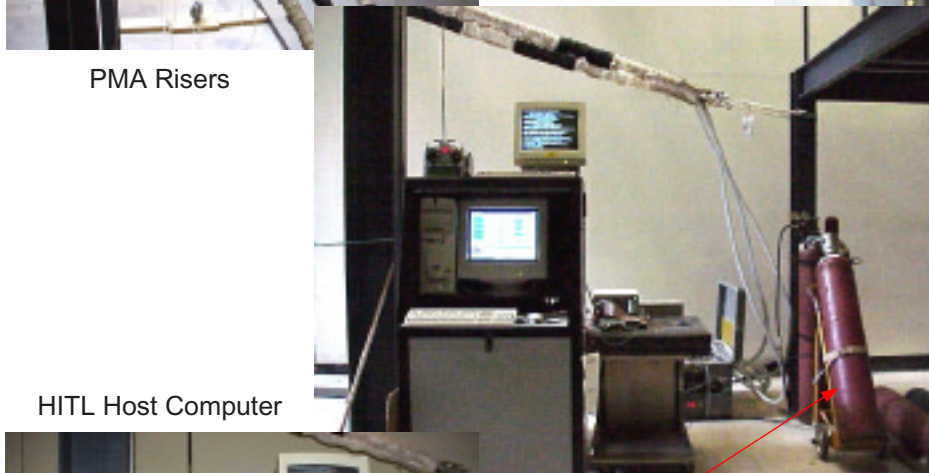
PMA Risers



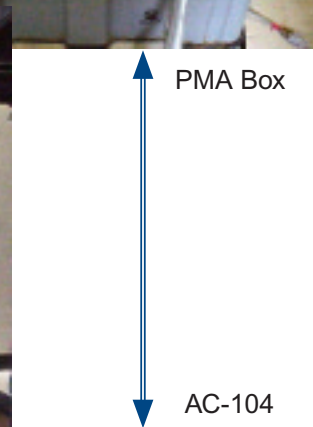
HITL Setup



PMA Box



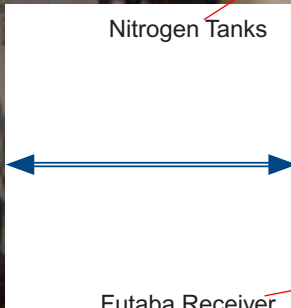
HITL Host Computer



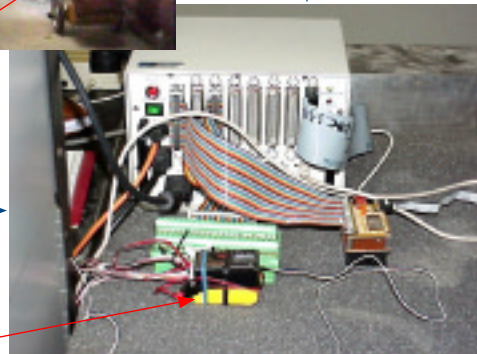
AC-104



Nitrogen Tanks



Futaba Receiver



*Hardware-in-the-loop simulation set-up for AGAS.*

## Structures, Structural Dynamics, Composite Mechanics, Fracture and Fatigue

**D**emands in the design and analysis of high performance aircraft require understanding of air vehicle behavior under a variety of loads and operating conditions. Emphasis is placed on both computational and experimental methods. Development and validation of computational tools for solving large order structural problems is under progress. A PC-based program to design composites for aircraft structures satisfying strength and stiffness requirements is under development. In the structural dynamics area, understanding the dynamic behavior of helicopters and weapons accuracy is studied.

Computationally, finite element programs such as NASA/STARS and MSC/NASTRAN are used for modeling and simulation. In support of the numerical simulation, an experimental set-up to determine natural frequencies and mode shapes using a portable Bruel & Kjaers

PULSE system is being incorporated in the Structural Dynamics Lab. Aging aircraft and its impact on the Naval aircraft is receiving increased attention. The department develops and delivers aircraft structural failure, fracture and fatigue related courses to NAVAIR and Navy's aviation repair and maintenance depots. In support of these efforts, the Structures Laboratory supports Instron and MTS testing machines. Instron closed loop servo hydraulic machines are used to understand structural fatigue behavior, life extension and assessment by means of studies on crack propagation and component testing. The lab also supports an acoustic emission set-up for damage detection and monitoring of structures.

**Personnel:** Professor E. Roberts Wood, Research Assistant Professor Ramesh Kolar, Professor Don Danielson (Mathematics Department), CDR Mark Couch, USN

### Current Work

#### **Weapons Accuracy Analysis of Comanche Helicopter**

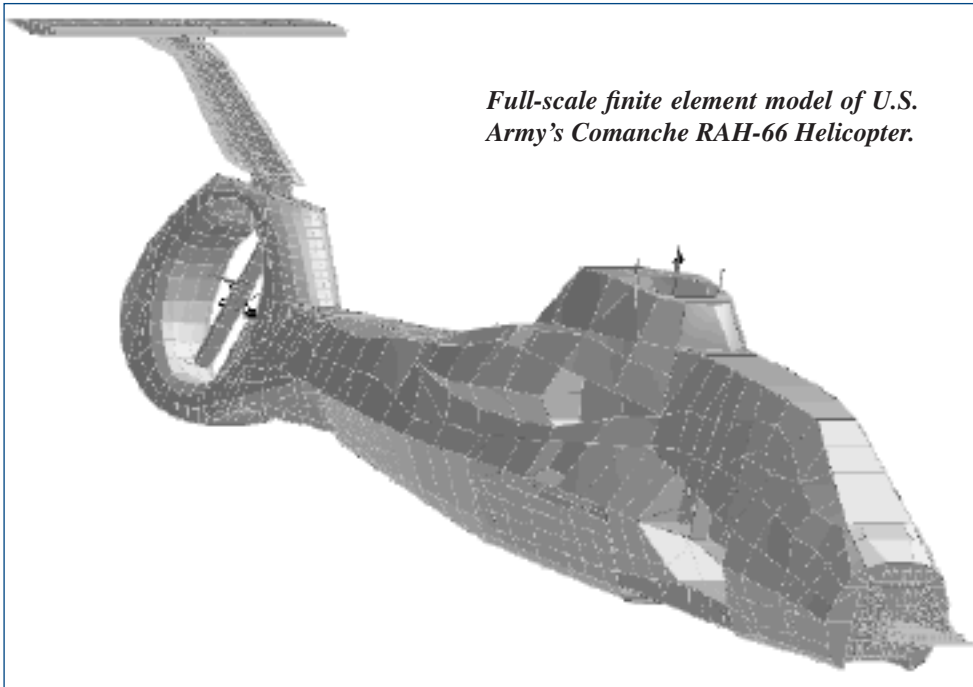
*Sponsor/Collaborator: U.S. Army Yuma Proving Ground*

- Modeling and simulation of the U.S. Army's Comanche RAH-66 full-scale model with the gun and accessories
- Modal analysis, steady state analysis, and studies that include effects of the structural flexibility on the weapon accuracy

#### **Multi-Disciplinary Finite Element Analysis of Flight Vehicles**

*Sponsor/Collaborator: NASA Dryden Flight Research Center*

- Modeling and simulation studies of flight vehicle
- Comparison studies for large structural dynamic and aeroelastic problems using state-of-the-art computational software



*Full-scale finite element model of U.S. Army's Comanche RAH-66 Helicopter.*

#### **Fatigue and Fracture**

*Sponsor: NAVAIR*

- Develop and deliver aircraft structural failure, fracture and fatigue related courses and related computational fatigue analysis tools
- Develop probabilistic strain life prediction methodology based on experimental data for airframe life assessment and extension programs
- Develop methods and techniques for aeroelastic tailoring and damage detection and repair.



# Propulsion and Gas Dynamics

## Turbopropulsion and Gas Dynamics

Advanced aircraft engine technology is taught from first principles to conceptual engine and preliminary component design. Current research is aimed at aero-structural design optimization, test and validation, and development of new instrumentation and measurement techniques. Practical instruction and advanced research in air-breathing propulsion and gas dynamics are the charter functions of the Turbopropulsion Laboratory (TPL), an NPS Research Center, and the Gas Dynamics Laboratory (GDL). Realistic (engine-scale) experimental studies are enabled by, for a university, unusually high power levels and the large scale or high speeds of the test rigs. Exploiting this uniqueness, the emphasis is on developing and applying advanced measurement techniques to obtain data to validate emerging computational (CFD) predictions and new designs. In addition to the application of CFD codes to experimental

test geometries, a new geometry package has been developed to optimize the aero-structural design of a compressor or fan rotor. Also, high cycle fatigue (HCF) structural test techniques are being developed for use in Navy spin-pit facilities at the Navy Air Warfare Center-Aircraft Division (NAWC-AD), and small turbo-engine variants for UAVs or missiles are being explored experimentally. Current programs are tied to Navy-critical (IPTET and HCF) engine R&T programs, and very close coordination is maintained with Propulsion and Power, AIR 4.4, at the Naval Air Warfare Center. [Past research sponsors have included, in addition to the Navy (NAVAIR and ONR), the Army, NASA, DARPA, Rolls-Royce and Sundstrand].

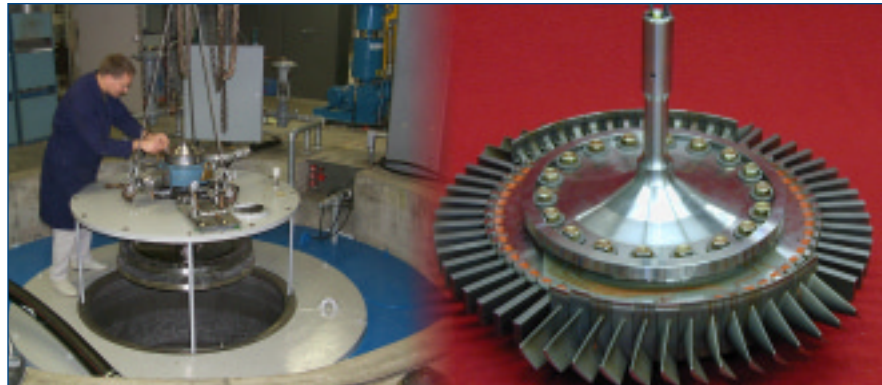
**Personnel:** Professors Ray Shreeve and Garth Hobson, Engineer Doug Seivwright, Technicians Rick Still and John Gibson, Programmer Zafer Aktan.

## Current Work

### HCF/Spin Test Research: The Navy Rotor-Spin Research Facility

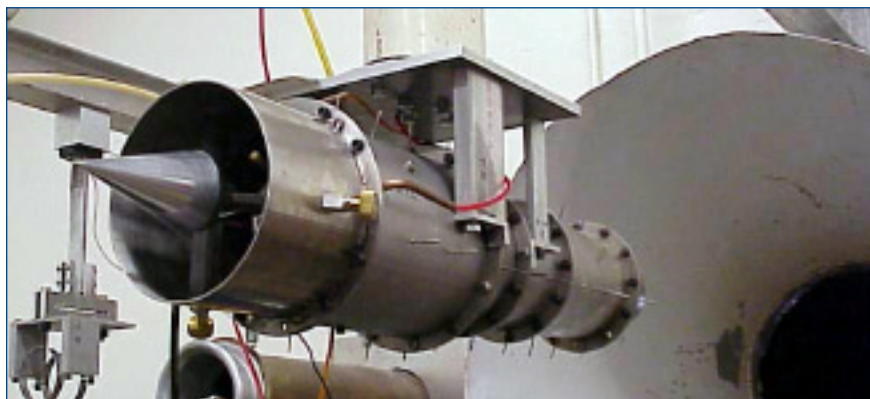
*Sponsors/Collaborators: NAVAIR (jointly with AF/WPAFB, Pratt & Whitney, Hood Technology Corporation)*

- Explore eddy-current, air and oil-jet methods to excite resonant vibrations in advanced engine turbine and fan rotors, in vacuum spin tests (shown at right)
- Measure blade response during resonance using strain gauge and non-contact tip-timing (NSMS) measurement techniques
- Transition developed techniques for the Navy's use at NAWCAD
- Bladed-disk XTE 66 low-pressure turbine rotor (shown at right) test completed
- P&W F119 development fan test to follow



### Small-Engine Propulsion

- Ten twenty-pound thrust turbo-jet engines are used to examine potential propulsion systems for UAVs and high-Mach number missile concepts
- Instrumented test capability established for sea-level static and low speed flight conditions



*Twenty-pound thrust turbo-jet engine.*

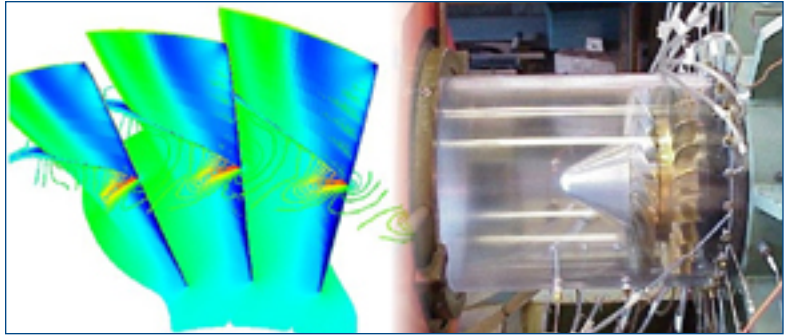


## Current Work

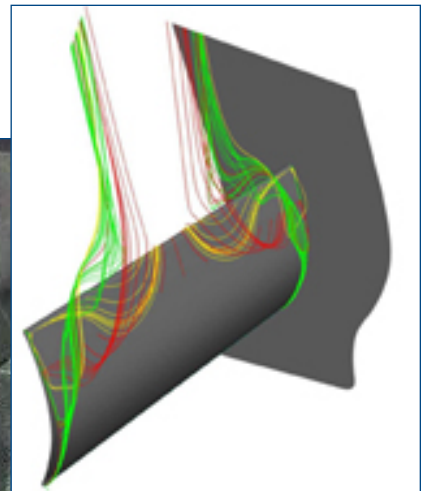
### Advanced Fan and Compressor Development

*Sponsor/Collaborator: NAVAIR*

- Reference transonic fan stage [Sanger, NASA GRC] currently under evaluation
- Pressure-sensitive paint technique being developed for rotor application
- 3D geometry package developed for aero-structural optimization
- Sweep investigated and Sanger rotor performance improvements obtained
- Application to other CFD reference test-case designs is underway
- Large (60x10 inch test section with 15 blades) CD compressor cascade (shown at right)
- 3-Component LDV mapping of stalling passage flow
- Full Navier-Stokes Code CFD predictions (shown at far right)
- Investigation of vortex shedding



*University-unique transonic compressor test rig (right), SWIFT and IDEAS codes are used to validate CFD methods for 3D design and aero-mechanical design optimization (left).*



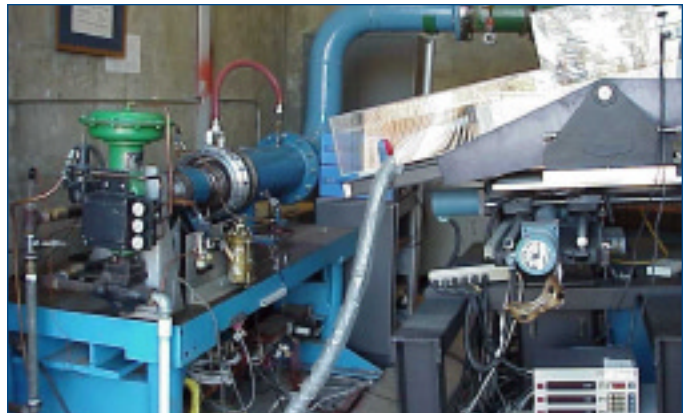
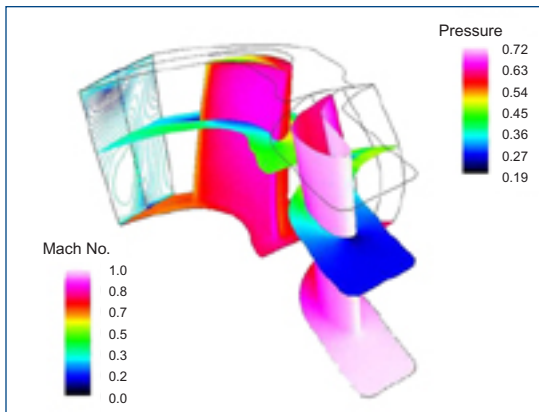
### Turbine Tip Leakage

*Sponsor: NAVAIR*

- High-speed test rig rebuilt and re-instrumented for tip-clearance study (shown below at right)
- SSME Alternate Fuel Pump

Turbine (single stage) installed

- LDV measurement technique developed using aerodynamic window
- Comparison of SWIFT code computations of flow through blade rows (shown below at left)



## Rocket and Ramjet Propulsion

Current and future applications of high-speed propulsion systems on both military and commercial platforms require a thorough understanding of the existing gas dynamic and chemical processes within these systems. Propulsion systems commonly investigated include solid propellant and liquid propellant rocket engines, ramjets, and pulse detonation engine systems.

The Rocket Propulsion and Combustion Laboratory (RPCL) supports research programs and instructional laboratories related to advanced chemical propulsion systems. Many of the high-speed propulsion courses in the department involve experience at the laboratory investigating advanced systems and their related technologies. The laboratory has received support from a variety of government agencies, including the Office of Naval Research, Air Force Research Lab, and Naval Air Warfare Center Weapons Division as well as commercial companies such as General Electric Aircraft Engines and Pratt and Whitney.

The laboratory consists of three hot-fire test cells, two cold flow testing areas, and a control room capable of monitoring experiments throughout the lab. The laboratory is capable of testing both solid and liquid rocket engines up to 500-lbs. thrust. Ramjets can be tested with

vitiated air heaters which provide airflow rates up to 8 lb./s second at 750 K. Gaseous and liquid-fueled pulse detonation engines can be tested up to 100 Hz operation, and comprehensive conventional and optical diagnostics are available to characterize performance and system operation.

The hardware and infrastructure of RPCL is complemented by a wide range of diagnostic capabilities required for the investigation of various propulsion systems. Some of the diagnostic capabilities existing at the lab include a Phase Doppler Particle Analyzer (PDPA), Malvern particle analyzers, a copper vapor laser system for Particle Image Velocimetry (PIV), a Nd: YAG laser, high speed intensified CCD cameras, visible and infrared imaging systems, spectroradiometers, and a wide range of additional laser systems. PC based, high-speed data acquisition systems are located throughout the laboratory and are used to monitor the diagnostic systems, thermocouples, and high frequency pressure transducers.

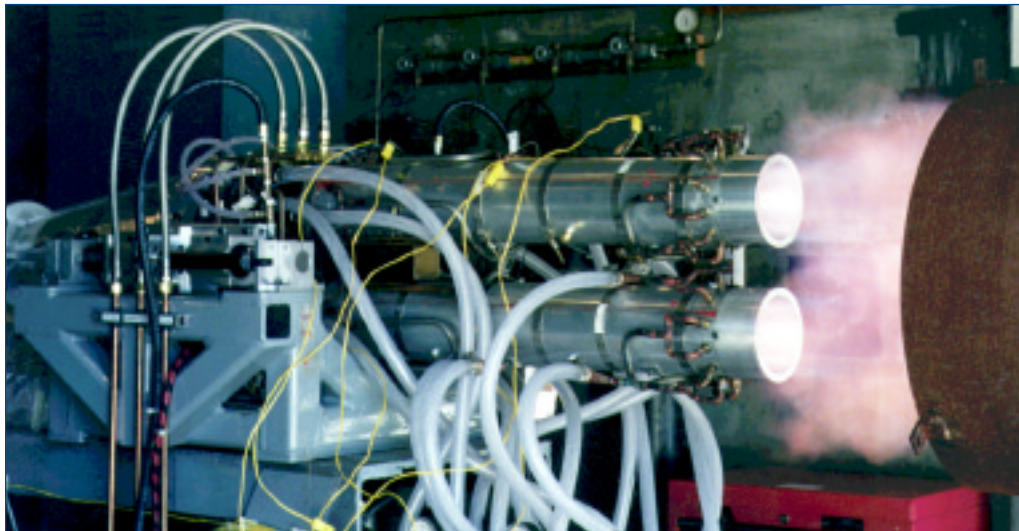
**Personnel:** Distinguished Professor David W. Netzer, Professor Oscar Biblarz, Research Assistant Professor Christopher M. Brophy, Research Assistant Professor Jose O. Sinibaldi, Aerospace Technician Harry E. Conner

## Current Work

### Pulse Detonation Engine Research and Development

*Sponsors/Collaborators: Office of Naval Research, General Electric Aircraft Engines, Pratt & Whitney*

- Research and development of a valve-less Pulse Detonation Engine (PDE)
- Optimization of the detonation initiation process for gaseous and liquid fueled mixtures through energy and shock focusing techniques
  - Investigation of detonation propagation through JP10 aerosol mixtures
  - Development of optically accessible PDEs to study fundamental physical processes within a PDE cycle using state of the art diode laser based optical diagnostics
- Systems integration and evaluation of air-breathing liquid-fueled PDEs at up to 100Hz operation
- Evaluation of PDE's acoustic and emissions signature
- Investigation of hybrid PDE configurations

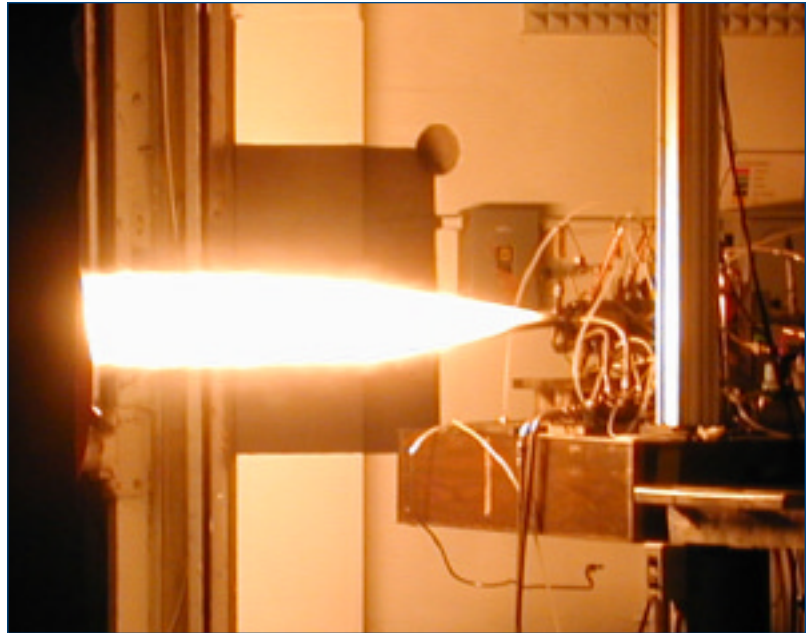


*Pratt & Whitney's PDE during testing at NPS.*

### Plume Signature Characterization and Modification

*Sponsors/Collaborators: Air Force Research Laboratory, Ballistic Missile Defense Office, NASA Marshall Space Flight Center, Sierra Engineering*

- A small liquid-fuel rocket engine is used to vary certain operating parameters and quantify the change in the plume characteristics
- An infrared(IR) camera is used to image the IR emission and provide spatial information on the engines IR plume signature
- Additional information describing what species are present in the plume can be obtained through the use of the laboratory's IR spectroradiometer
- Soot concentrations and soot optical properties across rocket plumes are determined by simultaneously measuring transmission ratios at various visible and near IR wavelengths
- Results are then fed back to modelers who then use the information to improve the performance and the accuracy of the modeling codes to predict the overall signature on a particular engine systems.



*RP-1 / O<sub>2</sub> Rocket Plume for Signature Studies.*

### Transpiration Cooling for Rocket Engine Combustors

*Sponsor/Collaborator: Sierra Engineering*

- Alternate technique for cooling liquid rocket engine combustor segments
- New fabrication technologies permit coolant to be injected as specific critical areas
- A substantial reduction in the required coolant flow may be obtained.



### Pulse Detonation Rocket Engine (PDRE)

- Research and development of a liquid-fueled PDRE
- Direct Numerical Simulations (DNS) of detonation wave diffraction and re-initiation
- Experimental investigation of system performance, heat transfer characteristics, and integration with air-breathing PDE system

*NPS PDRE under testing conditions.*



## Avionics

Avionics represents a growing part of the total acquisition and life-cycle cost of aircraft. Topics in this field include computer design and architecture, communications systems, computer algorithms, computer networking, sensors, software engineering, and systems engineering as applied to new and legacy avionics systems. Typical research projects include the analysis of methods for upgrading legacy avionics systems, both hardware and software; analysis and development of parallel computing architectures and algorithms for sensor processing and information fusion; and development of sensors and systems for improved situational awareness.

In the Avionics Laboratory, modern computer-aided design and development tools are used to study fleet related problems including real-time software design, fusion algorithms, software re-hosting, software engineering methods, open systems, and computer architectures. Schematic and HDL circuit design tools and modern software development tools are hosted on ten Pentium III and IV class PCs for hardware and software development. The Machine Transferable AN/AYK-14 Support Software System (MTASS/M) software development tools are hosted on a Sun SPARCstation 10. A simulation of the F/A-18 C/D avionics systems capable of executing the Mission Computer Operational Flight Program (OFP) is hosted on an SGI Octane workstation. The F/A-18 tools are used to investigate problems related to legacy avionics support.

**Personnel:** Associate Professor Russ Duren, CDR Mark Couch, USN, Technician AT2 Jim Bishoff.

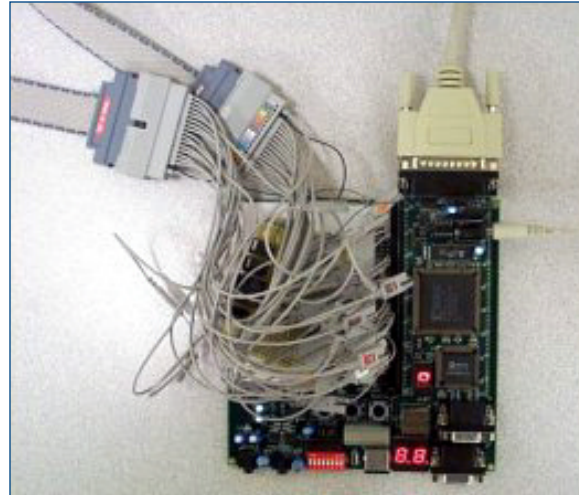
## Current Work

### F/A-18 C/D Avionics Architecture Study

*Sponsor: Naval Air Warfare Center-Weapons Division*

- Analysis of upgrade options for the C/D avionics system
- Design of a FPGA-based replacement for the AN/AYK-14 VHSIC Processor Module
- Re-hosting of legacy software development tools

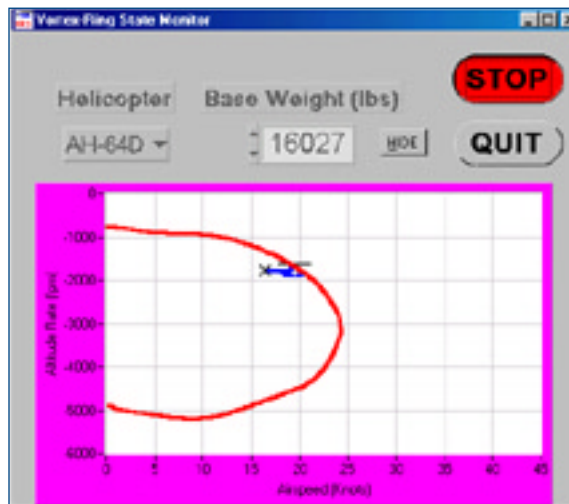
*Designs are loaded into FPGAs using the PC parallel cable.*



### UHF Electrically Scanned Array Radar Test Bed Processing Architecture Study

*Sponsor: Naval Air Systems Command*

- Analysis of parallel computing architectures
- Investigation of computer benchmarks for radar processing



### Development of Pilot Aids

*Sponsor: Office of Naval Research (Navy Science Assistance Program)*

- Development of a Vortex-Ring State Warning System
- Development of a low airspeed measurement system for helicopters

*Vortex Ring State Warning Device.*

### Analysis of Tracking Characteristics and ID Contributions of Diverse Systems and Data Sources for Multiple Source Integration

*Sponsor: Naval Air Warfare Center-Aircraft Division*

- Development of MATLAB models to investigate tracking and data fusion

### Development and Simulation of an Air-Ground Retargeting System

*Sponsor: Naval Air Warfare Center-Aircraft Division*

- Development of a MATLAB model to investigate real-time retargeting systems.



# Rotary Wing Aircraft Technology

The study of the aeromechanics of flight by rotary wing and Vertical/Short Take-Off and Landing (V/STOL) aircraft continues to be a complex combination of the aerodynamic, propulsive and structural disciplines. Work in these areas is supported by the Rotorcraft Laboratory. The Rotorcraft Laboratory is designed to provide a multifaceted approach to the problems encountered in flight by rotary wing and Vertical Take-Off and Landing (VTOL) aircraft. The testing portion of the lab consists of flight testing, structural dynamics testing, wind and water tunnel testing, acoustic testing and flight simulation. The jewels of the rotorcraft lab are the two OH-6A helicopters. Through a cooperative agreement with Mississippi State, one helicopter is certified for use in flight testing. Cockpit components of the other helicopter are used as part of a flight simulator developed with Advanced Rotorcraft Technologies in Mountain View, CA. The fuselage of the second helicopter serves as part of the structural dynamics testing at NPS. Making use of additional test facilities at NPS,

models have been developed for both the water tunnel and wind tunnel to study circulation control. In conjunction with the Physics Department at NPS, an acoustic test facility has been developed.

The modeling and simulation portions of the lab consists of several computers using commercial-off-the-shelf software such as NASTRAN®, DYTRAN®, MATLAB®, Simulink®, Maple®, and FlightLab® to study problems in rotor dynamics, acoustics, structural dynamics and flight performance. The Joint Army/Navy Rotorcraft Analysis and Design (JANRAD) computer program was developed at NPS to perform performance, stability and control, and rotor dynamics analysis during preliminary helicopter design efforts.

**Personnel:** Professor E. Roberts Wood, Associate Professor Russ Duren, Research Assistant Professor Ramesh Kolar, and CDR Mark Couch, USN, Aerospace Technician Don Meeks and AT2 Jim Bishoff.

## Current Work

### Rotor Dynamics Modeling and Simulation

*Sponsor: Army Research Office*

- Research in aeroelastic stability of rotor systems applying NPS Non-linear Rotor Dynamics Code
- Application of non-linear blade dampers to eliminate ground and air resonance of rotor systems

### Acoustic Modeling, Simulation and Testing

*Sponsor: U.S. Army Comanche Program Office*

- Correlation of actual and analytical helicopter aural detection criteria
- Development of computer program, MICHIN, for mapping aural detection of helicopters in tactical situations.

### Blade Torsional Dynamics

*Collaborator: NASA Ames Research Center*

- Application of Myklested-Holzer methodology for predicting inflight torsional response of rotor blades
- Study of time history of UH-60 model rotor torsional response from DNW Wind Tunnel tests

### Vortex Ring State Aerodynamics

*Collaborator: Naval Air Systems Command and NASA Ames Research Center*

- Contributor to NASA V-22 Tiltrotor Aeromechanics Assessment Report
- Analysis of blade loads and rotor power required by H-34 in VRS flight regime

### Rotary Wing Unsteady Aerodynamics

- The influence of wake spacing and phases on induced drag of oscillator rotor blade during hover flight
- Derivation of a lift deficiency function for a helicopter rotor blade in forward flights

### Higher Harmonic Control

*Sponsor: U.S. Army Research Office*

- Reduced effectiveness of HHC due to control system flexibility and free-play
- Application of single layer of shed wake vorticity to explore power benefits of HHC

### Flight Simulation and Modeling of OH-6A

*Collaborators: Advanced Rotorcraft Technologies, Inc. and Mississippi State University*

- Design and fabrication of a two-seat tiltrotor flight simulator using components from OH-6A helicopter
- Full-scale HHC flight tests of an OH-6A helicopter



**Hummingbird I:** A remotely-piloted helicopter (25 hp; 10 ft. diameter 2 bladed rotor) modified for simulated flight testing by NPS faculty and students.

# Aircraft Combat Survivability

An essential aspect in the education of the warfighter is the study of aircraft combat survivability. The core of the survivability discipline was developed by NPS Distinguished Professor Emeritus Robert E. Ball. The courses and research areas emphasize the operational considerations and analytical methodologies necessary to design aircraft, both fixed-wing and rotary-wing, that are survivable in the combat environment. The resources available to educate the warfighter include the Survivability and Lethality Assessment Laboratory, Distance Learning and Short Courses, and a variety of multi-discipline survivability and lethality related graduate courses at NPS.

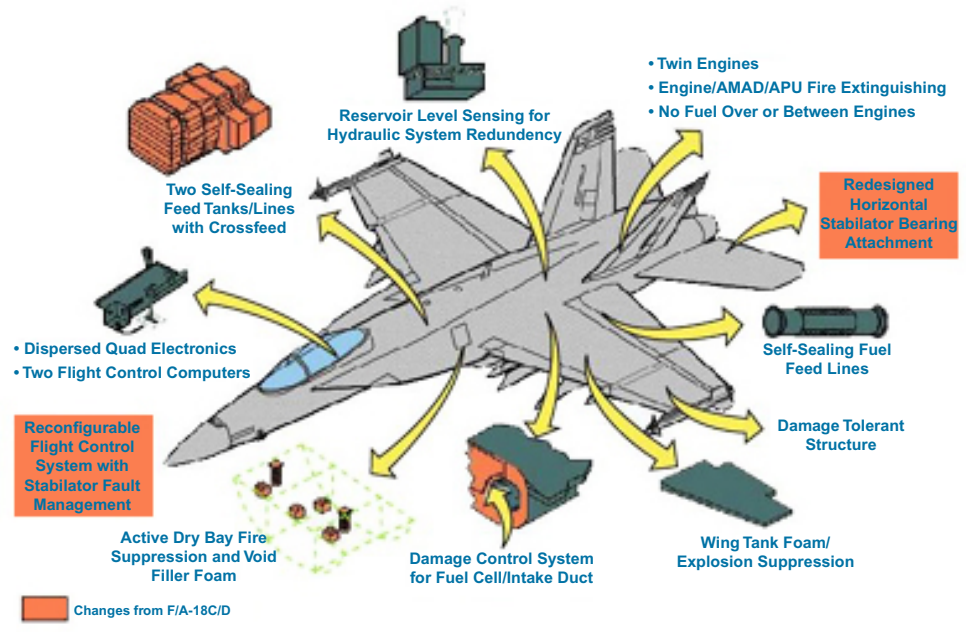
The survivability and lethality modeling communities have developed a large number of computer programs for assessing the survivability of U.S. platforms and the lethality of U.S. weapons. Several of these programs have been adopted by the three services as “approved models” and are stored in the Model Repository of the Survivability/Vulnerability Information Analysis Center (SURVIAC). NPS is tasked by the Combat Survivability Branch of the

*Survivability through design.*

Naval Air Systems Command (AIR-4.1.8) to collect and install the SURVIAC programs, as well as other major computer programs used in survivability and lethality studies. These are maintained in the NPS survivability lab located in the classified War Lab on the NPS main campus.

**Personnel:** CDR Mark Couch, USN, Distinguished Professor Emeritus Robert Ball, and Professor Morris Driels (Mechanical Engineering Department)

## F/A -18E/F Vulnerability Reduction Features (U)



## Current Work

### Aircraft Survivability Distance Learning and Short Courses

- Provide engineers, managers, and those interested in the field, the opportunity to learn about the fundamentals of survivability engineering and the application of these fundamentals to actual aircraft
- Material presented is also directly applicable to missile survivability
- Offers graduate credit and is taught via Video Teleconferencing to various organizations of all three services
- Short course is a 4-5 day course oriented to the continuing education of design engineers, analysts, project managers and members of the field activities associated with design, analysis, acquisition, logistic support, operations, or repair of aircraft weapons systems hardware.
- Course is available to both DoD personnel and DoD contractors
- Cooperative agreement with the Joint Technical Coordinating Group/Aircraft Survivability provides funding for Distance Learning and Short Courses
- Recent DoD organizations taking advantage of this course are Naval Air Systems Command (Patuxent River and China Lake), Joint Strike Fighter Office (Crystal City and Edwards AFB), and U.S. Army Evaluation Center (Aberdeen Proving Ground).

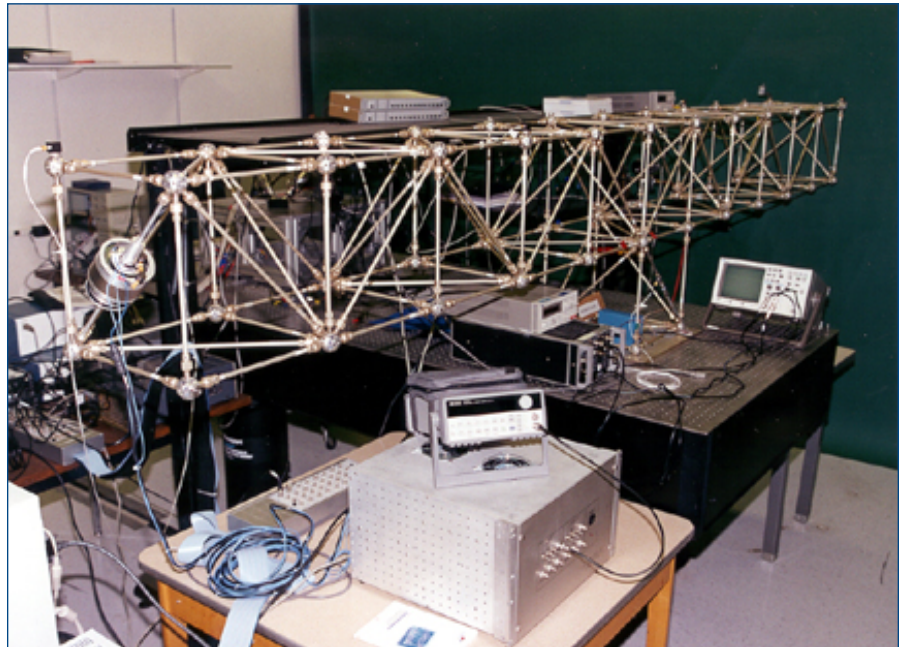


# Spacecraft Systems, Attitude Control and Smart Structures

In astronautics, the emphasis is on teaching and research in spacecraft systems, spacecraft structures, dynamics and control. Several unique laboratories have been developed to provide hands-on experience in the design, analysis, and testing of space systems and subsystems and experimental research on current problems on DoD spacecraft. During the last ten years, four Ph.D., seven Engineer, and thirty-four M.S. theses have been completed using these laboratories.

- The Spacecraft Attitude Dynamics and Control Laboratory is used to perform research on developing improved control techniques for attitude control of flexible spacecraft and flexible robotic manipulators. The emphasis has been to develop improved control laws for fast slew maneuvers of flexible spacecraft. The laboratory has three simulators to validate the improved control techniques experimentally: Flexible Spacecraft Simulator (FSS), Space Robot Simulator (SRS), and Three-Axis-Spacecraft Simulator (TASS). The FSS simulates attitude motions of the spacecraft in one axis. The SRS consists of

a two-link manipulator with rigid and flexible links. The TASS simulates a free floating spacecraft with a platform that incorporates rate gyros, sun sensors, and magnetometers, three reaction wheels and a laptop computer. The

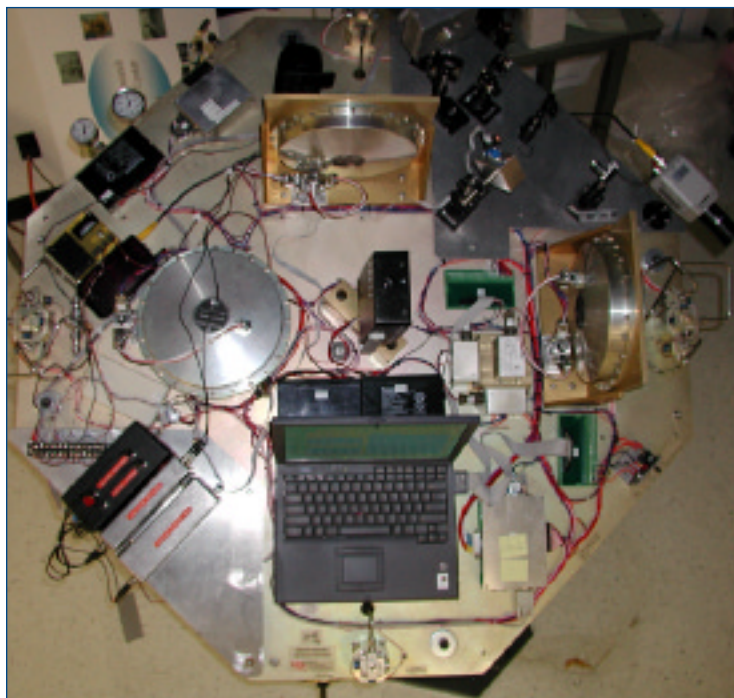


*NPS Space Truss.*

platform floats on a spherical air-bearing stand, thus giving the simulator three degrees of freedom for attitude control.

The simulator also has an optical payload consisting of a fast steering mirror, jitter control system, camera for acquisition, tracking and pointing. The integrated system is used as a simulator of a relay mirror spacecraft.

- The Smart Structures Laboratory is used to perform research on active vibration control, vibration isolation, and fine pointing by using smart sensors and actuators. This laboratory has three main experiments: Ultra Quiet platform (UQP), Positioning Hexapod and the NPS Space Truss. The UQP is used for testing control algorithms for vibration isolation of an imaging payload. It has six piezoceramic actuators and a geophone sensor. The Position Hexapod is used for testing control algorithms for both vibration isolation of an imaging payload and fine steering. It is based on the arrangement of six self-supporting electromagnetic voice coil actuators with in-line accelerometers and position sensors. The NPS Space Truss is used for testing control algorithms for active structural control and vibration isolation. The overall dimension of the truss is 3.76 m long, 0.35m wide, and 0.7 m tall. It has



*Three-Axis Spacecraft Simulator with integrated optical payload.*

piezoceramic struts as actuators and a linear proof mass actuator as source of disturbance.

- The FLTSATCOM Laboratory consists of a qualification model of the Navy communications satellite, FLT-SATCOM, and ground TT&C system. This laboratory is kept operational in cooperation with Naval Satellite Operational Center, for use by students in classes and by NAVSOC for analyzing on-orbit anomalies. Commands are sent to the satellite for wheel spin-up, firing of thrusters and rotation of solar array drive.

- The Satellite Servicing Laboratory is a new laboratory used to develop and operate a servicing spacecraft simulator to conduct research into autonomous rendezvous, docking and control of a small manipulator vehicle. The servicing spacecraft simulator floats on a granite table using air pads to provide a friction less 2-D simulation of on-orbit operations.



***FLTSATCOM Spacecraft and Ground Test Equipment.***

**Personnel:** Professor Brij Agrawal, Assistant Professor Michael Spencer, Associate Professor Roberto Cristi (Electrical and Computer Engineering Department), National Research Council Research Associates Hong-Jen Chen and Marcello Romano

## Current Work

### **Vibration Suppression and Isolation in Imaging Spacecraft**

*Sponsor: Secretary of the Air Force*

- Develop improved adaptive control techniques to isolate imaging payload for spacecraft vibration
- Develop improved adaptive control techniques to steer and isolate/suppress vibration for imaging spacecraft
- Develop improved adaptive control techniques for reducing vibration of large structures

### **SWARM Formation Satellite System Design**

*Sponsor: National Reconnaissance Office*

- Design satellite system for swarm configurations (nine daughter satellites flying in swarm configuration around a single “mother” spacecraft)
- Spacecraft is an EHF communications satellite in low earth orbit

### **Methods of Slewing by Investigating Control Algorithms and Methods**

*Sponsor: Secretary of the Air Force*

- Develop torque profiles for slew maneuvers minimizing settling time at end of maneuver
- Develop analytical models to compare bang-bang, input-shaped and optimal control techniques

### **Bifocal Relay Mirror Technology Development**

*Sponsor: National Reconnaissance Office (Directors Innovative Initiative Award)*

*Collaborators: Air Force Research Laboratory and Boeing SVS*

- Develop acquisition, tracking, and pointing techniques for bifocal relay mirror spacecraft
- Develop test bed consisting of three-axis simulator and optical payload consisting of fast steering mirrors and tracking camera
- Analytical and experimental testing of control techniques for spacecraft, fast steering mirrors, and tracking sensor



# Spacecraft Guidance, Control and Optimization

Guidance technology is an important component of military spacecraft. Advanced guidance systems architecture and supporting algorithms have been developed at the NPS Astrolab and the Space Technology Battlefield Laboratory for high-speed precision guidance and control of space vehicles and ballistic missiles. A significant breakthrough was achieved here by a revolutionary approach to the design of feedback laws. In this approach, the “laws” are determined on-line with an adaptive nonlinear model instead of the traditional off-line design and implementation. This system can adapt to changing mission objectives while maintaining optimal performance.

Two software packages have been developed at NPS

in this field. DIDO is the implementation of a pseudospectral method invented at Astrolab. It is a one-of-a-kind method to provide automatic “adjoint sensitivities” or covector information for complex nonsmooth problems. ACAPS is another software developed for the Jet Propulsion Laboratory for the preliminary design of interplanetary aeroassisted missions. It has also been used by Raytheon to support JPL missions.

**Personnel:** Associate Professor I. Michael Ross, Associate Professor Fariba Fahroo (Mathematics Department), Visiting Research Associate Hui Yan, Visiting Research Associate Daewoo Lee

## Current Work

### Astronautical Guidance

*Sponsors: Air Force Research Laboratory, Draper Labs, and Jet Propulsion Laboratory*

- Perturbation guidance work focuses on a new approach to solving linear time-varying systems with quadratic cost and possibly linear constraints by an online solution to the boundary value problem; a model-predictive control circumvents the problems associated with solving the matrix Riccati equation.
- Real-time trajectory generation is exploited for launch vehicle abort guidance
- Development of ACAPS is an ongoing project that supports JPL missions.

### Spacecraft Control

*Sponsors: Air Force Space Command, Naval Space Command*

- Differential geometric methods (differential flatness, dynamic inversion etc.) for nonlinear control systems are explored by way of pseudospectral methods.
- Optimal periodic control theory is used to design and control “spacecraft swarm” formations.
- Globally-minimum-time slew maneuvers for flexible spacecraft with zero residual vibration is achieved by targeting the final state of the spacecraft to lie on a smooth manifold defined in terms of residual vibrations.

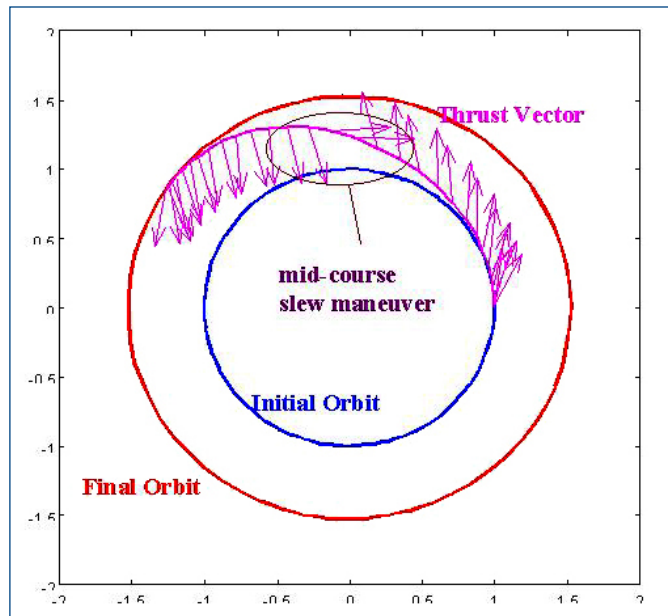
### Nonsmooth Dynamic Optimization

*Sponsors: Air Force Research Laboratory, Draper Labs, Naval Surface Weapons Center, and Jet Propulsion Laboratory*

- Nonsmooth systems appear in almost all

branches of engineering. A new revolutionary approach to solving dynamic optimization problems is the main focus of this research effort. Legendre, Chebyshev and Sinc pseudospectral methods are being developed for solving nonsmooth dynamic optimization problems.

- DIDO is a reusable software package, which is an implementation of various pseudospectral methods. It is being used for the design of minimum-time cyclic solar-sail trajectories, optimizing aerocapture maneuvers, low-thrust trajectories, rigid body maneuvers and many other problems.



**Optimal Low-Thrust Orbit Transfer: Maneuver obtained by DIDO. The thrust vectors are positioned at optimal points known as the Legendre-Gauss-Lobatto points. Optimal guidance is achieved by real-time computation of a perturbed system.**

# Research, Centers of Excellence and Collaborative Efforts

The research program at NPS exists to support the primary mission of graduate education. While maintaining the upper division course content and programs at the cutting edge, research also challenges students with creative problem solving experiences on DoD relevant issues, advances DoN/DoD technology, and solves warfare problems. Research in Aeronautics and Astronautics is focused on topics of critical importance to military users. Faculty and students participate in the full spectrum of research, from basic 6.1, as demonstrated in a computational study of abrupt wing stall, to the challenges facing today's warfighter, as demonstrated in the current development of an affordable guided airdrop system. Classified research at NPS offers additional opportunities to keep pace with an increasingly complex defense posture in today's world.

Current research thrusts and underlying issues have been addressed previously under the Areas of Concentration. Sponsored research provides funding for most of the faculty and student research conducted in the Department of Aeronautics and Astronautics. An

historical overview of the sponsored research program is shown in Figure 1.

The Navy funds almost fifty percent of the Aeronautics and Astronautics research. Sources of sponsorship for the FY2001 program are shown in Figure 2.

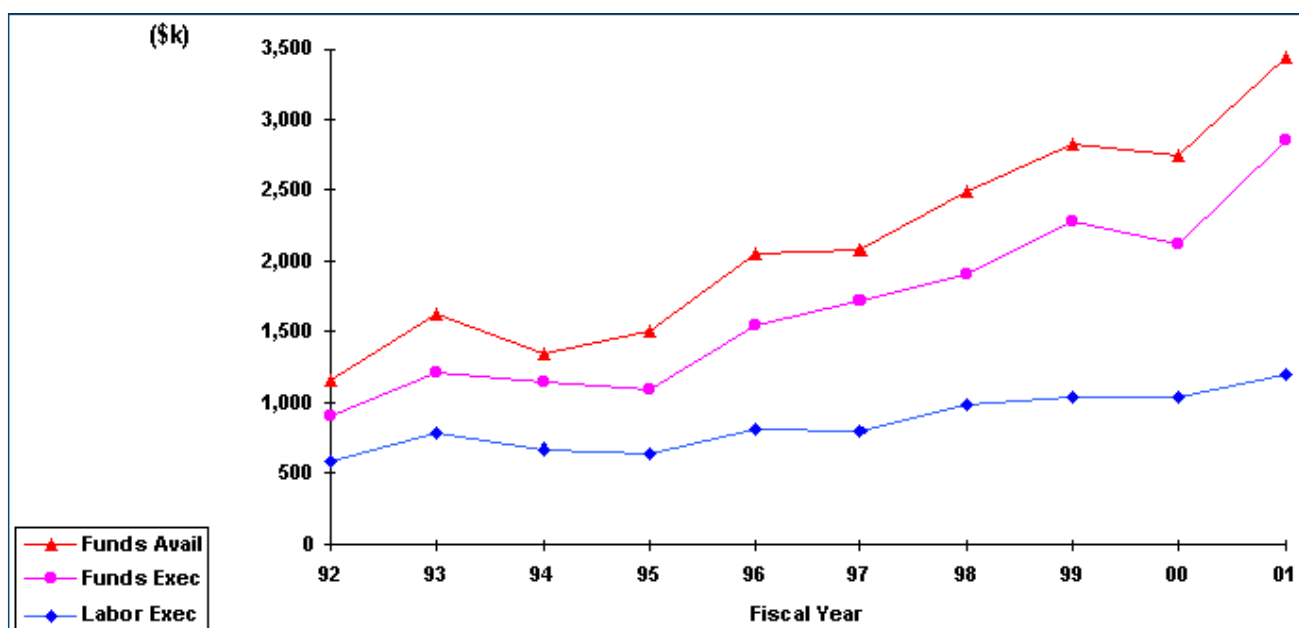
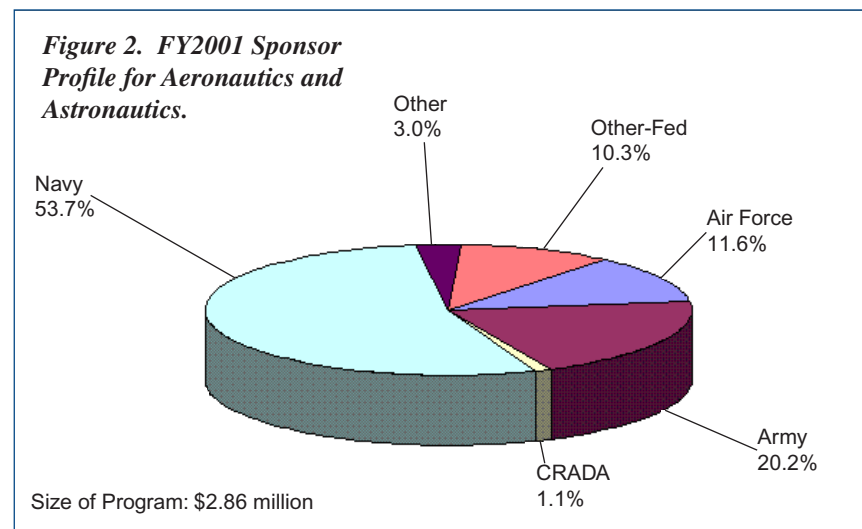


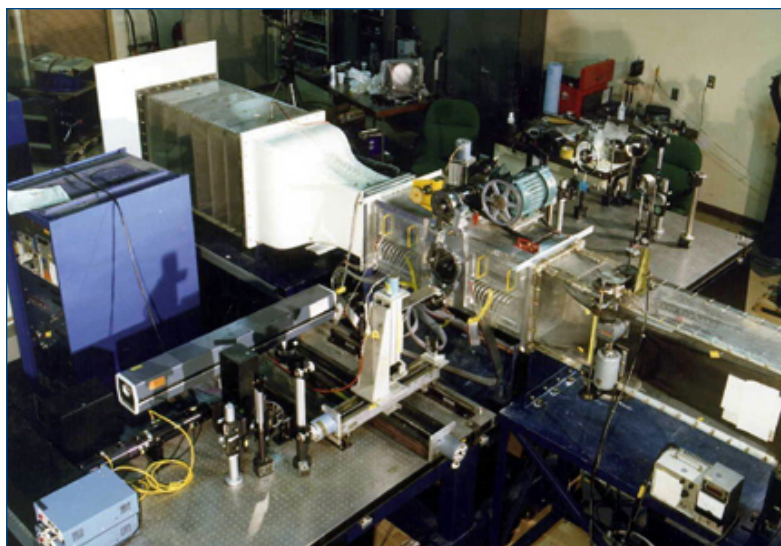
Figure 1. Funding Profile of Sponsored Programs in Aeronautics and Astronautics.

### **Technology Transfer**

The Naval Postgraduate School has an active technology transfer program. The most common forms of technology transfer are the publications and presentations of the faculty and students. Other technology transfer efforts of the Aero/Astro faculty include Cooperative Research and Development Agreements (General Electric Aircraft Engines, Mississippi State University, Advanced Rotorcraft Center), Small Business Technology Transfer (Stirling Dynamics, Scientific Systems Company), and Small Business Innovative Research (TDA Research Inc.).

### **Research Centers of Excellence**

Through the concentration of faculty expertise in a specific technical area, several research centers of excellence have been formed within the Department of Aeronautics and Astronautics. Some of these centers are a direct result of a



*Dynamic Stall Wind Tunnel at the NAVY-NASA Joint Institute for Aerospace Sciences.*

collaborative effort with other DoD agencies, federal agencies, or universities.

- **NAVY-NASA Joint Institute for Aerospace Sciences**

was formed in 1986 through a Memorandum of Understanding with the Ames Research Center (ARC) of the National Aeronautics and Space Administration (NASA). The purpose of the Institute is to provide NPS students with opportunities to perform their thesis research in an ARC Laboratory, to involve NPS faculty and students in NASA scientific and engineering projects, to develop space courses and seminars for NPS and ARC scientists and engineers to refresh and strengthen professional knowledge, and to encourage the enrollment of federal employees for graduate study at NPS with the possibility of performing their thesis research at ARC.

- **Vertical Flight Technology Center** is an interdisciplinary center formed to support the Army/Navy/NASA/FAA National Rotorcraft Technology Center (NRTC) at Ames Research Center, Moffett Field, California. The Center assists NRTC in developing the required design, engineering and manufacturing technologies for military and commercial rotorcraft.

- **Aerodynamic Decelerator Systems Center** was established through a Memorandum of Understanding among the U.S. Army Soldier and Biological Chemical Command, Natick Soldier Center (NSC), the U.S. Army Yuma Proving Ground (YPG), and the Naval Postgraduate School (NPS) to foster the advancement of aerodynamics decelerator systems research and technology among government agencies, academia, and non-profit public institutions. The NSC has the DoD mission for personnel, cargo, and precision airdrop systems research and technology development. YPG is the U.S. Army development test agency for airdrop systems. NPS has extensive expertise in advanced mission planning and guidance, navigation and control (GN&C) algorithm development and rapid prototyping of GN&C capabilities.

## **FY2001 Research Sponsors**

### Navy

- Naval Research Laboratory
- Office of Naval Research
- Naval Air Systems Command
- Naval Air Warfare Center-Aircraft Division
- Naval Air Warfare Center-Weapons Division
- Naval Surface Warfare Center-Carderock Division
- Naval Surface Warfare Center-Crane Division
- Naval Aviation Depot

### Army

- Army Research Office
- Yuma Proving Ground
- Comanche Program Office
- Army Materiel Command

### Air Force

- Air Force Research Laboratory
- Secretary of the Air Force

### Other Federal

- National Aeronautics and Space Administration
- National Reconnaissance Office
- National Oceanic and Atmospheric Agency

### Other

- Florida A&M University
- Draper Labs
- California Institute of Technology

### Industry

- General Electric Aircraft Engines
- Stirling Dynamics



- **Spacecraft Research and Design Center** consists of four state-of-the-art laboratories: Spacecraft Attitude Dynamics and Control Laboratory, Smart Structures Laboratory, FLTSATCOM Satellite Laboratory, and the Spacecraft Design Laboratory. The Center provides students with hands-on experience in the design, analysis, and testing of space systems and sub-systems and with the facilities to do experimental research.

- **Turbopropulsion Laboratory** was the first research center formed at NPS. Active since 1964, it is committed to the advancement of turbomachinery and air-breathing propulsion. Emphasis has been on the technology of gas turbine engines. A specific research focus has been concentrated in past years on the aerodynamics of compressors and turbine engines required for such engine.

Faculty within the Department of Aeronautics

and Astronautics also interact with other Research Centers of Excellence at NPS. One such collaboration is with the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS). CIRPAS joins NPS, the Office of Naval Research and the California Institute of Technology in a collaborative effort to provide manned and unmanned air vehicle (UAV) flight services to the research, development, test and evaluation communities, as well as support for the development of concepts of operations (CONOPS) and operational missions. CIRPAS is located at the Marina Municipal Airport about 10 miles from NPS and McMillan Airfield, Camp Roberts, California. The Camp Roberts facility is approximately 100 miles south of Monterey and provides an isolated geographical location with abundant clear airspace, freedom from signal interference and a clear air corridor to the Pacific Ocean.

***Turbo-Propulsion Laboratory/Gas Dynamics Laboratory (TPL/GDL) Facilities: The unique set of three well-equipped laboratory buildings supports advanced instructional and research programs in air-breathing propulsion and high-speed flows.***

#### **Low Speed Laboratory**

- 600 HP Power Supply (Fan)
- Linear Cascade Wind Tunnel (60x10 inch test section)
- Radial Cascade Wind Tunnel (4 to 6 feet radius x 2 inch)
- 3-Stage Axial Compressor (36 inch tip diameter)
- VXI/PC Data, 3-Ch. LDV and Hot-Wire Systems



#### **Gas Dynamics Laboratory**

- 600 & 150 HP Compressors (2000 scfm, 10 & 20 atm.)
- Shock Tube (4 inch diameter)
- Supersonic Wind Tunnel (4 x 4 inches)
- Transonic Cascade Wind Tunnel (2 x 3 inches)
- Free Jet (1 inch)
- Rotor Spin Rig (50 HP @ 30, 000 RPM)
- Small Gas Turbine Test Cell and Free Jet
- VXI/PC Data, Scanivalve ZOCs, PSP, Schlieren



#### **High Speed Laboratory**

- 1200 HP Power Supply (12-Stage Axial Compressor 3 atm.)
- Transonic Compressor Test Rig
- Transonic Turbine Test Rig
- Turbocharger Test and Calibration Free Jet
- Rotor Spin Research Facility (56 inch diameter. x 24 inch)
- VXI/PC Data (200Ks/sec), 2-Ch. LDV, 2-Ch. NSMS

## CIRPAS Assets



*Altus ST*



*Gnat 750*



*UV-18A Twin Otter*



*Pelican Surrogate UAV*



*AN/MPQ-64 Sentinel Air Surveillance and Target Acquisition/Tracking Radar*

*Predator*



### Collaborative Efforts

Not all research collaborative efforts have been formalized by the creation of a Center. Interaction with other research laboratories and organizations is ongoing and provides faculty and students additional opportunities.

- Naval Air Warfare Center-Patuxent River
- Naval Air Warfare Center-China Lake
- Naval Air Warfare Center- Pt. Mugu
- U.S. Air Force Phillips Lab
- NASA Dryden Flight Research Center
- Jet Propulsion Laboratory
- Stanford University
- Purdue University

- University of California Santa Barbara
- University of California Los Angeles
- NASA Glenn Research Center
- General Electric Aircraft Engines
- The Pennsylvania State University
- California Institute of Technology
- Air Force Research Laboratory
- Sierra Engineering
- Draper Laboratories
- Massachusetts Institute of Technology
- Texas A&M
- Lockheed-Martin
- Raytheon

# Faculty and Staff

## Tenured and Tenure Track

Distinguished Professor Max F. Platzer, Chairman  
Distinguished Professor David W. Netzer  
Professor Brij N. Agrawal  
Professor Oscar Biblarz  
Professor Garth V. Hobson  
Professor Conrad F. Newberry  
Professor Raymond P. Shreeve  
Professor E. R. Wood  
Associate Professor Russ Duren  
Associate Professor Richard M. Howard  
Associate Professor Isaac I. Kaminer  
Associate Professor I. Michael Ross  
Assistant Professor Michael G. Spencer

## Research Faculty

Research Professor M.S. Chandrasekhara  
Research Associate Professor Kevin D. Jones  
Research Associate Professor Oleg Yakimenko  
Research Assistant Professor Chris M. Brophy  
Research Assistant Professor Ramesh Kolar  
Research Assistant Professor Jose Sinibaldi  
Visiting Research Associate Motomu Nakashima

## Instructors/Lecturers/Visiting Faculty

Distinguished Visiting Professor James Mar  
CDR Mark A. Couch, Military Faculty  
Senior Lecturer Shesh K. Hebbar  
Visiting Associate Professor Barry Leonard  
Dr. James L. Fobes, Federal Aviation Agency Aviation  
Security Chair

## Emeriti Faculty

Distinguished Professor Emeritus Robert E. Ball  
Professor Emeritus Louis V. Schmidt

## National Research Council Research Associates

Dr. Hong-Jen Chen  
Dr. Vladimir Dobrokhodov  
Dr. Marcello Romano

## Technical Staff

Jerry Lentz, Aerospace Physicist  
Spiro Michopoulos, Aerospace Engineer  
Doug Seivwright, Aerospace Engineer  
Harry Conner, Aerospace Technician  
Donald Meeks, Aerospace Technician  
Rich Still, Aerospace Technician

## Faculty Biographies

**Max F. Platzer**, Distinguished Professor and Chairman

Doctor of Technical Sciences, Technical University of Vienna, Austria, 1964

**Research Interests:** Aerodynamics, Aeroelasticity, Flight Mechanics, Flight Propulsion

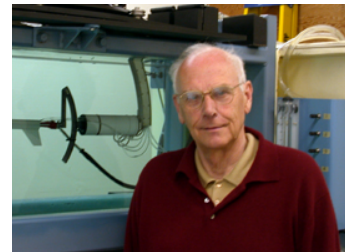
**Previous Experience:** Lockheed-Georgia Research Laboratory, Marietta, GA, 1966-1970,

NASA George C. Marshall Space Flight Center, 1960-1966,  
Technical University of Vienna, 1957-1960

**Honors and Awards:** Fellow, American Institute of Aeronautics and Astronautics  
Fellow, American Society of Mechanical Engineers

NASA Incentive Award for Superior Achievement

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**Brij N. Agrawal**, Professor and Associate Chairman

Ph.D. Syracuse University, 1970

**Research Interests:** Spacecraft Attitude Control, Smart Structures, Spacecraft Design

**Previous Experience:** COMSAT Labs, 1969-1979

International Telecommunications Satellite Organization (INTELSAT), 1979-1989

**Honors and Awards:** Associate Fellow, American Institute of Aeronautics and Astronautics

**Contact Info:** 831-656-3338, agrawal@nps.navy.mil





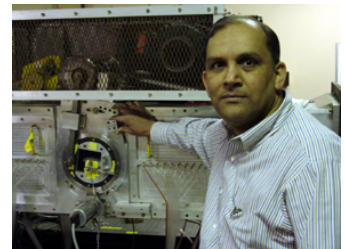
**Oscar Biblarz**, Professor and Associate Chairman  
 Ph.D. Stanford University, 1968  
**Research Interests:** Aerospace Propulsion and Power, Aerodynamics, Lasers  
**Previous Experience:** GTE Electrical Products, 1987-1989  
 Hughes Aircraft Company, 1961-1963  
 AiResearch Manufacturing Company/Garrett Corporation, 1959-1961  
**Contact Info:** 831-656-3096, obiblarz@nps.navy.mil



**Christopher M. Brophy**, Research Assistant Professor  
 Ph.D. University of Alabama Huntsville, 1997  
**Research Interests:** Rocket Propulsion and Combustion  
**Previous Experience:** National Research Council Postdoctoral Fellow, Naval Postgraduate School, 1997-1999  
**Contact Info:** 831-656-2327, cmbrophy@nps.navy.mil



**M. S. Chandrasekhara**, Research Professor  
 Ph.D. The University of Iowa, 1983  
**Research Interests:** Aerodynamics, Instrumentation, Measurement Techniques, and Sensors  
**Previous Experience:** Florida State University, 1986-1987  
 TSI, Inc., 1984-1986  
 Stanford University, Joint Institute of Aeroacoustics, 1983  
**Honors and Awards:** Associate Fellow, American Institute of Aeronautics and Astronautics  
**Contact Info:** 831-656-5038, mchandra@nps.navy.mil



**Mark A. Couch**, CDR, USN  
 M.S. Aeronautical Engineering, Naval Postgraduate School, 1993  
**Research Interests:** Rotary Wing Aircraft, Aircraft Combat Survivability, Aeroelasticity, and Avionics  
**Related Experience:** Naval Aviator, 1984-present  
**Honors and Awards:** Admiral William A. Moffett Award for Academic Excellence, Naval Postgraduate School, 1993  
**Contact Info:** 831-656-2944, macouch@nps.navy.mil



**Russell W. Duren**, Associate Professor  
 Ph.D. Southern Methodist University, 1991  
**Research Interests:** Digital Avionics Architecture, Rotary Wing Aircraft  
**Previous Experience:** Lockheed-Martin Tactical Aircraft Systems (formerly General Dynamics, Inc.), 1983-1996  
 R-TEC (Reliance Telecommunications Electronics Company) Systems, 1979-1983  
 Texas Instruments, Inc., 1978-1979  
**Honors and Awards:** Senior Member, Institute of Electrical and Electronic Engineers  
 Myril B. Reed Outstanding Paper Award, 34th Midwest Symposium on Circuits and Systems, 1991  
**Contact Info:** 831-656-5039, rwduren@nps.navy.mil



**S. K. Hebbar**, Senior Lecturer

Ph.D. University of Maryland, 1976

**Research Interests:** Experimental Fluid Mechanics and Aerodynamics

**Previous Experience:** Tuskegee University, 1985-1987

NASA Ames Research Center, 1983-1985

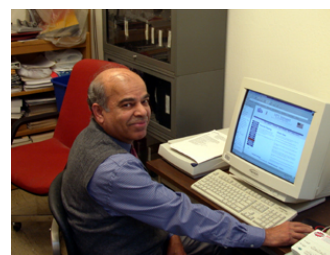
National Aerospace Laboratories of India, 1965-1983

University of Maryland, 1976-1976

**Honors and Awards:** Associate Fellow, American Institute of Aeronautics and Astronautics

Outstanding Aerospace Engineering Professor Award, Tuskegee University, 1987.

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**Garth V. Hobson**, Professor

Ph.D. Penn State University, 1990

**Research Interests:** Aerospace Propulsion and Power, Propulsion, Computational Fluid Dynamics

**Previous Experience:** Council for Scientific and Industrial Research (CSIR), South Africa, 1980-1989

**Honors and Awards:** Director's Award for Innovative Engineering, CSIR, 1983

Associate Fellow, American Institute of Aeronautics and Astronautics

**Contact Info:** 831-656-2888, gvhobson@nps.navy.mil



**Richard M. Howard**, Associate Professor

Ph.D. Texas A&M University, 1987

**Research Interests:** UAVs, Aircraft Performance and Flying Qualities, Flight Dynamics, Flight Test, Missile Aerodynamics

**Previous Experience:** Surveyor and engineer, various small engineering and surveying firms, 1976-1982

**Honors and Awards:** RADM John J. Schieffelin Award for Excellence in Teaching, 1992

**Contact Info:** 831-656-2870, rmhoward@nps.navy.mil



**Kevin D. Jones**, Research Associate Professor

Ph.D. University of Colorado, 1993

**Research Interests:** Aerodynamics and Aeroelasticity

**Previous Experience:** National Research Council Postdoctoral Fellow, Naval Postgraduate School, 1993-1996

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**Isaac I. Kaminer**, Associate Professor

Ph.D. University of Michigan, 1992

**Research Interests:** Unmanned Air Vehicles, Modeling and Simulation, Flight Controls, Conventional Weapons

**Previous Experience:** Boeing Commercial Airplanes Company, 1985-1992

**Honors and Awards:** Carl E. and Jesse W. Menneken Award for Excellence in Scientific Research, 1998

**Contact Info:** 831-656-5040, kaminer@nps.navy.mil

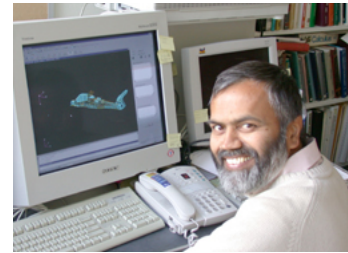


**Ramesh Kolar**, Research Assistant Professor  
Ph.D. University of Arizona, 1984

**Research Interests:** Structures and Composite Materials

**Previous Experience:** Aerospace Consultant, 1993-1997  
Aircraft Design Bureau, Hindusthan Aeronautics Limited, Bangalore, India, 1978-1980

**Contact Info:** 831-656-2854, rkolar@nps.navy.mil



**James W. Mar**, Distinguished Visiting Professor

Doctor of Science, Massachusetts Institute of Technology, 1949

**Research Interests:** Design of Aerospace Systems, Aerospace Structures, Aeroelasticity and Materials, Advance Filamentary Composite Materials

**Previous Experience:** Professor Emeritus, Massachusetts Institute of Technology, 1990-present

Massachusetts Institute of Technology, 1949-1990

**Honors and Awards:** Jerome C. Hunsaker Professor of Aerospace Education  
Member, National Academy of Engineering

Honorary Fellow, American Institute of Aeronautics and Astronautics

Exceptional Civilian Service Award (twice honored)

**Contact Info:** 831-656-2311



**David W. Netzer**, Distinguished Professor

Ph.D., Purdue University, 1968

**Research Interests:** Aerospace Propulsion and Power, Rocket Motor Plume Characteristics, Liquid and Solid Fuel Ramjets, Pulse-detonation Engines

**Previous Experience:** Aerojet General Corporation, 1962-1964

**Honors and Awards:** JANAAF Combustion Sub-Committee Annual Award  
RADM John J. Schieffelin Award for Excellence in Teaching, 1987

**Contact Info:** 831-656-2980, dnetzer@nps.navy.mil



**Conrad F. Newberry**, Professor

D.Env. University of California, Los Angeles, 1985

**Research Interests:** Aircraft and Missile Design, Environmental Security

**Previous Experience:** California State Polytechnic University, Pomona, 1964-1990; Rockwell International, 1984-1990; U.S. Environmental Protection Agency, 1980-1982; North American Aviation, 1951-1964

**Honors and Awards:** Fellow, American Institute of Aeronautics and Astronautics  
Fred Merryfield Design Award, American Society for Engineering Education  
John Leland Atwood Award for outstanding aerospace engineering educator, American Society for Engineering Education/American Institute of Aeronautics and Astronautics

Fellow, Institute for the Advancement of Engineering

Fellow, British Interplanetary Society

**Contact Info:** 831-656-2892, newberry@nps.navy.mil





**I. Michael Ross**, Associate Professor

Ph.D. The Pennsylvania State University, 1990

**Research Interests:** Spacecraft Guidance, Control and Optimization

**Related Experience:** Visiting Associate Professor, The Charles Stark Draper Laboratory, 1999-2001

**Honors and Awards:** Associate Fellow, American Institute of Aeronautics and Astronautics

Distinguished Leadership and Service Award, American Institute of Aeronautics and Astronautics

Carl E. and Jesse W. Menneken Award for Excellence in Scientific Research, 2000

Book Review Editor, Journal of Guidance Control and Dynamics

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**Raymond P. Shreeve**, Professor

Ph.D. University of Washington, 1970

**Research Interests:** Air-breathing Propulsion, Turbomachinery Aerodynamics, and Experimental Methods

**Previous Experience:** Boeing Scientific Research Laboratories, 1962-71.

Princeton University Gas Dynamics Laboratory, 1960-62.

**Honors and Awards:** Associate Fellow, American Institute of Aeronautics and Astronautics

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**Jose O. Sinibaldi**, Research Assistant Professor

Ph.D. University of Michigan, 1999

**Research Interests:** Rocket and Ramjet Propulsion, Optical Diagnostics for Combustion Processes, Detonation Wave Dynamics

**Previous Experience:** American Society for Engineering Education/Office of

Naval Research Postdoctoral Fellow, Naval Postgraduate School, 1999-2001

Consultant, various small engineering and software firms, 1992-1999

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